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Heavy Metals in different Compartments of the Wienfluss and Schwechat River

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How often we forget all time, when lone
Admiring Nature's universal throne ;
Her woods - her wilds - her mountains - the intense
Reply of Hers to Our intelligence!

(EDGAR ALLAN POE)

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1. Introduction

1.1. Heavy metals as toxicants and essential trace elements

There are various definitions for the term “heavy metal” (HM) in literature. In fact, Klaus Appenroth (private lecturer) from the Friedrich-Schiller university of Jena suggests that all transition metals, lanthanides, actinides as well as Al, Ga, In, Tl, Sn, Pb, Sb, Bi and Po can be named under the expression HM. Hollemann-Wiberg [1] defines HM as all metals with a density greater than 5 g/cm^3 . Moreover, they are omnipresent in the environment, which means that they can be found for instance in water, sediment or even in the air. In addition, the presence of HM is highly dependent on their physicochemical properties, their speciation and their distribution patterns. From the biological point of view, HM can be divided into two classes: class 1 corresponds to essential metals that are indispensable for living organisms such as humans, animals and plants. Class 2 involves non essential metals that do not play any known key role within the biotic metabolism [2].

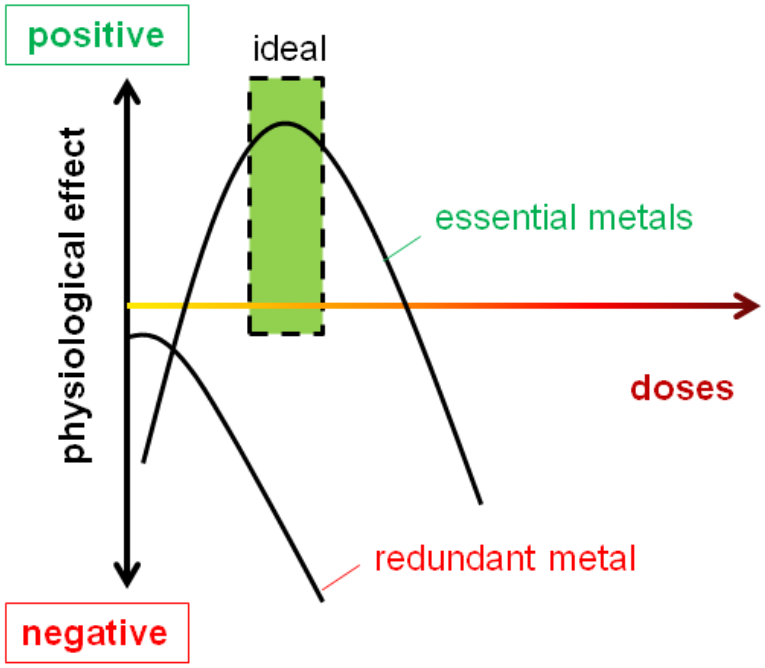

Figure 1 Dependency of the exposure-response relationship by dose, redrawn from Bliefert [2]

Unessential metals are not necessary for the living process, in fact, they may actually disturb metabolic processes when present even in small doses. On the other hand, essential metals are necessary in certain concentrations to sustain body functions [2]. Figure 1 shows the properties and dependency of physiological effects of trace elements on their dose. Whether an element is essential or not depends on its involvement in biochemical reactions within the corresponding organisms. At the beginning of the 16th century Paracelsus already described the relationship between dose and effect in the body as:

" *Dosis sola facit venenum* " (The dose permits something not to be poisonous) [3]

HM appear in nature as distinct species including ions, inorganic and organic complexes. They can be adsorbed to particles or appear in solutions, ranging from truly dissolved, via nano particles to colloids, they are also components of airborne dust [2]. Not all HM show the same degree of toxicity among organisms. Nickel, for example, is considered to be a pollutant for plants; however, some animals do need this metal in small traces to comply with their normal development. A short overview of the different toxic properties in plants and animals is given in the following table 1.

Table 1 HM ranking [2] (t = toxic; e = essential)

Metall	Plants	Animals	Density (g/cm^3)
Hg	t	t	13.59
Pb	t	t	11.34
Cu	e, t	e, t	10.20
Ni	t	e	8.90
Cd	t	t	8.65
Fe	e	e	7.86
Cr	—	e	7.20

In order to classify whether a trace element is properly working within a healthy growing plant and/or if it is essential for animals, there are three standards that should be taken into consideration [4]:

- Without a moderate input of the element the organism can neither grow in an appropriate manner nor finish its lifecycle.
- The element cannot be replaced completely by another one.
- The element is performing a direct influence on the organism and participates on its metabolism [4].

1.2. Solubility of heavy metals in soil

Soil is representing a key compartment of the terrestrial ecosystem both; the natural and the agricultural ecosystem. In addition, solids have the ability to absorb ions, which are included within the HM species, as mentioned before, onto their surface. Such ability may however vary from material to material. Furthermore, the pH level, redox ratios and the relative concentration of available ions are main factors influencing HM adsorption in soil. Moreover, the solubility products of water-insoluble compounds will as well determine the metal concentration in soil solutions [5].
Some of the most important HM regarding pollution in the environment are Pb, Cu, Cd, Ni, Cr as described in the European water frame directive (2000/60/EC) and therefore a very short description of their common appearance in soil-solution is given in the following paragraph:

Lead:

Different kinds of lead phosphates such as $Pb_5(PO_4)_3OH$, $Pb_3(PO_4)_2$ and $Pb_5(PO_4)_3Cl$ can be found in soil. Chloro-pyromorphite ($Pb_5(PO_4)_3Cl$) is the less soluble lead phosphate and it could additionally limit the solubility of Pb^{2+} in soil over a wide pH range. This occurs in particular in soil rich in phosphate, such as sludge [5].

Copper:

Generally, under most physical-chemical conditions, copper has been mostly found as its ion species, Cu^{2+}, in soil. Indeed, soil-copper is much more stable than any other copper mineral. Nevertheless there are exceptions under reducing conditions, on which delafossite ($CuFe_2O_4$) appears to be more stable than soil-copper [5]. While Cu^{2+} predominates in acidic soil solutions, including $CuSO_4$, $Cu(OH)_2$ and $CuCO_3$; other copper species such as Cu^{+}, CuCl, $Cu(Cl)_2^{-}$, as well as other organic copper complexes, are mostly found in soil solutions with higher pH levels[6].

Cadmium:

The dynamic equilibrium between the amount of adsorbed cadmium dissolved within the soil solution and the amount adsorbed within the soil in the solid phase depends on different factors including the pH level, the charge of the available complex, the stability of the cadmium complexes, the binding capacities of functional groups, and the concentration of competitive ions [7]. Cadmium has overall a higher mobility than many other HM as for example lead and copper, and it is available for plants in an easier manner [5].

Nickel:

The mobility of nickel in soil increases with decreasing pH level and with decreasing cation exchange capacity [8]. In addition, its solubility increases with decreasing pH level being more soluble than chromium [5].

Chromium:

Chromium appears in different oxidation states of which chromium (III) and (VI) are the stable and common ones. Their chemical behaviors vary however. Cr^{6+} occurs in anionic form, it is easily extracted out of soil and it represents the most toxic species. Chromate (CrO_4^{2-}), on the other hand, stands in pH dependent equilibrium with other forms of chromium (VI) such as $HCrO_4^{-}$. In addition CrO_4^{2-} is the prevailing species within pH levels higher than 6. In contrast, Cr^{3+} is hardly mobile and it is strongly adsorbed to soil particles. The solubility of Cr^{3+} decreases at a pH level greater than 4 [5].

1.2.1. Categorization of soil pollution

As a matter of fact, there are no threshold values in Austria or in the European Union for pollution in sediments of surface waters so far. However, there are some guidelines that can be used for this purpose, such as the natural geological background content, the available literature and data concerning the total content of soil pollution if aquatic organisms are negative affected by contamination. The use of soil thresholds could as well serve for this purpose. This distinct evaluations based on accumulation factors focused on Austrian background values are described in table 2 [9].

Table 2 Classification of the HM occurrence in Austrian sediments [10]; Values given in dry weight (d.w.)

Sediment Quality	Pb (mg/kg)	Cu (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)
Background value	36	40	0.5	36	39
Non-contaminated	48	53	0.75	48	53
Non-contaminated to moderately contaminated	96	106	1.5	96	106
Moderately contaminated	192	212	3	192	212
Moderately to heavily contaminated	384	424	6	384	424
Heavily contaminated	668	848	12	768	848
Heavily contaminated to extremely contaminated	1336	1696	24	1536	1696
Extremely contaminated	>1336	>1696	>24		>1696

1.2.2. Sources of heavy metals in the environment

HM can be emitted into the environment through both; natural and anthropogenic causes. The major recent causes of emission are however the anthropogenic sources [11]. HM, such as cadmium, copper, lead, chromium and mercury are important environmental pollutants, particularly in areas with high anthropogenic influences. Their presence in the atmosphere, soil and water, even in traces, can cause serious problems to all organisms. HM accumulation in soils is of particular concern in the agricultural production due to their adverse effects on food quality (safety and marketability), crop growth (due to phytotoxicity) [12–14] and environmental health (soil flora/fauna and terrestrial animals). The mobility of HM in the biosphere as a result of human activity such as cigarette smoking or industrial exhausts, has acquired higher importance throughout the last 150 years. In fact, this is an important geochemical cycling process. This is of course more evident in urban areas where various stationary and mobile sources release large quantities of HM into the atmosphere and into the soil, exceeding the natural emission rates [15, 16]. Overall, trace HM appear naturally in dissolved form in surface waters and their sediments see table 3.

Table 3 Background concentration of selected trace HM in running waters [2]

Element	Water (µg/L)	Suspended Sediment (mg/L)
Pb	0.1	12.5 to 50
Cd	0.08	0.15 to 0.6
Cr(6+)	2	40 to 160
Cu	0.2	10 to 40
Ni	0.2	15 to 60

1.3. Pb: Introduction

Lead belongs to group IV in the periodic table and appears in two stable oxidation stages: +2 and +4. In the world of environmental chemistry the Pb^{2+} is the dominant one. Elementary lead is slate blue, melts at 327 °C and vaporizes at 1744 °C. The low melting point allowed already primitive cultures of the past to smelt and work with it. The fact that this metal has a soft consistency allows its easy cutting and deforming, and it has been used therefore for a long time for tiling and pipe working. In the last twenty years a wide range of investigations in respect to lead issues in environmental materials, including soil, have been made [5].

1.3.1. Physiological properties

Lead has no known essential biochemical functions but it is nevertheless ubiquitously present at measurable concentrations in mammals and humans, due to global and regional anthropogenic contamination of air, water and soil. In fact, the health hazards of lead have been known since ancient times. Common pathways of lead exposure to mammals and humans include the inhalation of windblown lead-laden dust and the oral intake of lead through contaminated water and food. Soil ingestion is a risk factor for grazing animals as well as for ground living species of small mammals and for young children with hand-to-mouth behavior [17]. Moreover, lead can pass through the placenta, causing fetal lead exposure. In the same manner, lead can be transferred from the maternal blood to the milk and expose the weanling to serious health risks [18].

In adult humans, Pb compounds are mainly reabsorbed as aerosol to an extent of up to 70 % through the lungs and to an extent of 8 % through the gastrointestinal tract (GIT). After this reabsorption process, lead binds to hemoglobin and spreads quickly within the human body. In addition, lead creates insoluble $Pb_3(PO_4)_2$ in the bones and teeth in combination with phosphate. This will be stored for a long time (half life up to 30 years). The elimination process takes place through the kidneys (75 %) and the feces (15 %) [3].

1.3.2. Lead in the environment

The total anthropogenic lead deposit in Austria is generally estimated with 200 kt of which 40 % (about 75 kt) comes from the industrial, manufacturing and service sector. Furthermore, 1/4 (about 50 kt) comes from private households. Most of lead is accumulated in motor vehicles in private households, according to the Austrian statistical evaluations (Statistic AUSTRIA, 2007) and increases around 1 to 1.5 % per year [19]. Nowadays, 40 % of the lead production is used for batteries, the manufacturing of colors, munitions or balance weights. The most significant lead compound was the tetraethyl lead, which used to serve as an antiknock additive for gasoline engines and became forbidden in the year 1975. In order to clean engines, ethyldihalids (Cl, Br) are added, which react with lead forming PbBrCl that appears in the exhaust fumes [3].

1.4. Cu: Introduction

Copper represents the first transition element (Ib) in the periodic table. Cu^{2+} is indeed pretty stable in water, but the second ionization potential is much higher than the first one. This is the reason why many stable copper(I) species are capable of existing in the environment. Copper is one of the most important essential trace elements for plants and animals. Metallic copper shows a reddish color, it is shiny, malleable, and it possesses ductility properties as well as good heat and electrical conductivity [5]. Copper is perhaps the oldest metallurgical product known to have been extracted by humans. Its metallurgy has been widely known for thousand years before the Christian era. The name copper has been applied to the metal presumably in relation to the classical region of its mining in the island of Cyprus, where it was known as *aes Cyprium* - brass of Cypres [20].

1.4.1. Physiological properties

Copper represents for humans an essential trace element. Copper is a main part of many metalloenzymes e.g. cytochrome-oxidase, superoxide-dismutase, uricase, tyrosinase and others [3]. The human body contains copper at a level of about 1.4 to 2.1 mg per kg of body mass [21]. Stated differently, the recommended dietary allowance (RDA) for copper in normal healthy adults is quoted as 0.97 mg/day and as 3.0 mg/day [22]. Depending on the diet composition, copper can be absorbed to an extent of up to 40 % in the GIT, of which 15 % is already present in the gut. After its absorption, copper will bind to albumin and be transported to the liver. There, copper will bind to metallothionein (MT) that generally transmit copper to ceruloplasmin (CP). Due to the CP, copper will be spread in combination with plasma in the tissues. The renal elimination of copper (1 %) and its fecal elimination (up to 10 %) takes place within 72 hours. Moreover, sweat elimination of copper may possibly take place to an extent of up to 3 % [3].

1.4.2. Copper in the environment

Soil in urban districts presents five to ten times higher amounts of extractable copper than adjacent agricultural sectors due to the burning of wood products, fossil fuel and waste materials [23]. When copper is present in high amounts in the soil, it will migrate in solution to lower ground layers and be eventually eliminated through soil erosion. By the natural process of leaching, the amount of copper washed out from soil is actually low. Other sources of copper exposure include the emissions expelled during the metal extraction process of smelting, or sewage sludge and liquid manure from poultry and pigs fed with $CuSO_4$. Additionally, fungicides and algaecides containing copper as well as the use of this metal in the galvanic industry provide with common sources for high and excessive amounts of Cu^{2+} in soil [5]. Furthermore, copper and other metals enter the soil, and hence vegetation, from the atmosphere. Through this process, copper is able to reach mining areas and running waters by means of sewages and erosion. This will lead in turn to a high accumulation in fish and other living species, as well as located pollution in alluvial soil [23]. The highest amount of copper content in agricultural soil comes from spraying fungicides in fruit ranches, where that element annually reaches directly or indirectly the ground through e.g. leaf fall [24]. Nowadays, more than 50 % of the extracted copper will be used for the manufacturing of electric cables, coins, alloys e.g. bronze, dishes or herbicides [3].

1.5. Cd: Introduction

Cadmium represents an element from the II b group in the periodic table. It is a relatively rare metal that stands in position 67 within the abundance of elements. Cadmium is not generally believed to have a biological function and appears to be highly toxic in animals and plants [5]. However, recently, Lane and Morel [25] provided evidence of a biological role for cadmium in marine diatoms under conditions of low zinc, typical of the marine environment. Cadmium is a soft, malleable, ductile, bluish-white metal. It is similar in many respects to zinc and it has the ability to form complex compounds [26]. Unlike other metals, cadmium is resistant to corrosion and it is therefore used as a protective layer on other metals. As a bulk metal, cadmium is insoluble in water and is not flammable; however, it may burn and release toxic fumes in its powdered form [27].

1.5.1. Physiological properties

For humans the pathways in which Cd compounds will be absorbed in the lungs include aerosols (up to 50 %). Its absorption in the GIT (up to 5 %) depends on individual nutrition. After resorption, cadmium will be mainly bound to albumin and transported to the liver and kidneys. There, cadmium stimulates metal binding proteins such as MT [3]. Cadmium enters the enterocytes in the intestinal mucosa via transporter proteins and can induce MT synthesis. This metal is released from the intestinal mucosa slowly into the blood, with which it is mainly transported to the liver where it binds to MT. In this way, cadmium will be later transported, bound to MT, to the kidneys. The exact amount of cadmium that reaches these organs is nevertheless not known. The fact that cadmium binds to MT serves as a protective mean for the kidneys against its toxic effects. Tissue injury is most likely caused by “free” cadmium. Renal cadmium not bound to MT may occur as a result of “critical concentrations”. These may occur when the capacities of MT to bind and detoxify “free” Cd are exceeded due to either an acute high dose or through long term low level intake of Cd. Because of the binding of cadmium to MT and its low excretion rates, the biological half life of this metal is relatively long. In fact, humans can retain Cd for 10–30 years, which causes its high accumulation with age. Furthermore, its concentration in the human kidney renal

cortex has been proved to increase up to the age of 50 years and then decline [28]. This decline may be associated with renal tubule dysfunction, which leads to increased urinary excretion of cadmium. Excessive excretion of calcium and phosphorus, as well as other important bone minerals, can lead to osteomalacia, osteoporosis, and decreased mineral density and bone strength. “Itai-itai” disease is the Japanese name for this syndrome among people (mostly multiparous women over 50 years) living on a rice diet high in cadmium [17]. Deficiencies in iron and zinc can in turn increase the absorption toxicity of cadmium [29]. Overall, smokers are observed to have three to four times higher cadmium levels in blood, compared to non smokers, where a concentration of about 1 µg Cd/L blood is observed [3].

1.5.2. Cadmium in the environment

The environmental pollution with cadmium has been increasing significantly in the last decades as a result of the growing industrial production that involves the extracting, manufacturing and disposing of metals. In comparison to lead, copper and mercury that have been used for hundreds of years, cadmium reached a high implementation in the last century. In fact, more than half of the total industrial companies have used cadmium in the last 25 years [30]. Cadmium pollution in soil occurs during the metal extraction process of smelting (lead and zinc ore), through atmospheric emissions coming from manufacturing industries, the recycling of waste that contains cadmium, the burn of fossil fuels, among others [31]. Moreover, industrial and urban air pollution has shown to have a meaningful impact in the contamination of soils with cadmium in many industrial countries. Common utilities used today such as batteries, monitor tubes, color pigments (lightening traffic signs), hard plastic applied in children playing bricks are however classified as safe [3].

1.6. Ni: Introduction

Nickel belongs to the transition metals and corresponds to the group VIII b in the periodic table. Metallic nickel is a silver-white metal that can be easily polished and has hard and brittle properties. It can be applied in both; thermal and electrical conductivity. Nickel can occur in different kinds of oxidation states, but only Ni^{2+} is stable in soil and independent from the pH level or redox condition [5].

1.6.1. Physiological properties

Although not recognized until the 1970s, nickel plays an important role in the biological processes of microorganisms and plants [32]. The plant enzyme urease (an enzyme that assists in the hydrolysis of urea) and the enzyme NiFe-hydrogenase contain nickel. NiFe-hydrogenase contains in addition to this metal iron sulfur clusters. The NiFe-hydrogenase has a tendency to oxidize H_2. In addition, the nickel-tetra-pyrrole coenzyme, Cofactor F430, is present in the methyl coenzyme M reductase, which powers methanogenic archaea. Moreover, one of the carbon monoxide dehydrogenase enzymes consists of an Fe-Ni-S cluster [33]. Nickel dust can be absorbed through the lungs to an extent of up to 35 %. Water soluble nickel compounds, ingested orally, can be reabsorbed up to 10 %, whereas the non water soluble compounds are phagocytized in the GIT. Another way for nickel to enter the body takes place through the skin. After resorption, nickel will be mainly bound to albumin and spread out very quickly throughout the body. The highest nickel contents in the body are found within the kidneys, liver and lungs. Nickel elimination takes place mainly via renal excretion (90 %), the rest is eliminated through sweat and saliva [3].

1.6.2. Nickel in the environment

About 26700 t of nickel are emitted globally per year through the combustion of fossil fuels and the use of oils, which contain more nickel than coal. This is in fact the highest source for nickel pollution in the environment [34]. Indeed, the amount of nickel contained in diesel

exhaust may be drastically high [35]. The fact that these anthropogenic influences represent an evident source for nickel contamination is reflected in the decreasing concentration of nickel, lead, zinc and copper in green areas as the amount of roads decline [36]. The combustion of coal represents the second highest emission source followed by nickel-mining centers or nickel smelters. There are also many natural sources for nickel as it is part of dust from meteors, volcanic exhausts, salt-laden aerosols from sea waves and is set free through among others, activities, forest fires [34]. The highest record for chromium and nickel in the country side comes from flying ash, which contains high amounts of these metals [37]. The average content of nickel in coal and fly ash is given in table 4.

Table 4 General amount of nickel in coal and flying ash [38] (mg/kg)

Substance	Ni
Coal	15
Fly ash	
bituminous	11
sub-bituminous	1.8
Brown coal	13

Plants that grow in non contaminated soil or ground free from serpentine, a mineral containing high amounts of Ni, generally exhibit a nickel level of 0.1 to 5 mg/kg [39–43]. Overall, the amount of nickel in plants reflects the content of that element in the ground. This amount depends on the ratio of the soluble nickel ions to their replenishment rate [40, 44]. It has been proven that the interchangeable nickel in ground is proportional to the degree of acidity. In addition, the nickel input due to its concentration in plants is also increasing and plays today as well an important role in regards to the amount of nickel in soil [42, 45, 46]. In the same way as with other metal cations, the increase of the soil pH level is related to liming, which is in turn an efficient and practical agent to decrease toxic levels of Ni^{2+} within the ground [47]. Nickel is mostly used in the steel industry. Smaller amounts are used in the manufacturing of cookware, batteries, jewelries, spectacle frames, coins, buttons, among many others [3].

1.7. Cr: Introduction

Chromium is a d-transition element, which belongs to the VI b group in the periodic table. It has been used since 1877 in steel industries and since 1926 for chrome plating. It is grayish, brittle and it can be brightly polished. In addition, the metal is highly resistant against oxidation. This is the reason why it is applied in corrosion-proof alloys. The application of chromium in alloys increases their hardness and mechanical abrasion strength. Moreover, chromium appears in the environment in two oxidation states: Cr^{3+} and Cr^{6+}, from which Cr^{3+} represents the most stable one [5].

1.7.1. Physiological properties

The main properties of chromium have been verified for the first time in the year 1955 through diet experiments with rats [48]. People can be exposed to chromium when eating or drinking, breathing and through skin contact with chromium compounds. Given that the level of chromium in air and water is generally low, most of chrome exposure and its uptake takes place when eating food products that contain Cr^{3+}. In fact, Cr^{3+} occurs naturally in many vegetables, fruits, meats, yeast and grains. Furthermore, the way in which food is prepared, together with its storage, may alter the chromium contents in food products. For example, when food is stored in steel tanks or cans chromium concentrations might rise. Nevertheless it is important to mention that Cr^{3+} is an essential nutrient for humans and its shortage could cause heart problems, disruption of the metabolism and diabetes. The uptake of an excessive amount of Cr^{3+} can however be problematic and have a negative impact on health causing the development of skin rashes, for instance. Cr^{6+} is dangerous to human health, especially for people who work in the steel and textile industry, and it is known to cause various health effects. Those who smoke tobacco also have a higher chance of exposure to chromium. When Cr^{6+} appears, for example, in leather products, it can cause allergic reactions, such as skin rashes. Other health problems that are caused by Cr^{6+} include:

- Upset stomach and ulcers
- Respiratory problems
- Weakened immune systems

- Kidney and liver damages
- Alteration of genetic material
- Lung cancer

The several health hazards associated with exposure to chromium depend on the oxidation state of this metal. Chromium in its hexavalent form is for example toxic. Adverse effects of the hexavalent form on the skin include ulcerations, dermatitis, and allergic skin reactions [49]. The daily consumption of chromium for humans is estimated at around 60 µg. In addition, chromium is part of the glucose-tolerant factor that plays a main role for the metabolic system. Chromium can be absorbed through the skin, as well as through the lungs to an extent of up to 70 % and via the GIT up to 2 %. People who are not suffering from chromium poisoning have the highest chromium content (around 0.6 mg/kg) in kidneys. Furthermore, the chromium concentration in healthy people appears to be about 0.2 mg/kg within the liver and around 0.02 mg/kg within the brain. The elimination of this metal is mostly renal [3].

1.7.2. Chromium in the environment

Basically, the highest amount of chromium in the environment is the result of anthropogenic interventions, such as the release by the metallurgical industry. Chromium oxide is emitted from electric arc furnaces in form of small particles. According to the collection of data in the U.S. [50], the production of ferrochrome products is representing the main anthropogenic source. Even after adopting measures to avoid air pollution, approximately 12360 t are still emitted per year. The second biggest source for atmospherical chromium is the production of heavy-duty bricks, which emits 1630 t of chromium per year. This is closely followed by coal combustion that produces about 1564 t per year. In addition, the steel industry emits around 520 t per year [5].There are however some natural sources from which chromium is released, such as blown away ground dust or volcanic activities. Furthermore, the disposal of flying ash on the countryside seems to cause the highest deposit of chromium in soil. These values are shown in table 5. Due to the fact that flying ash carries a relatively high content of chromium, areas surrounding coal plants appear to have concentrated amounts of this metal [51]. Although flying ash can contribute to increase the content of chromium in soil, plants growing in those soils do not seem to have an elevated uptake of chromium [52]. Less

significant chromium sources, on which chromium catalysts are used, include abrasion from asbestos, braking pads from vehicles, and dust [5].

Table 5 General amount of chromium in coal and flying ash [38] (mg/kg)

Substance	Cr
Coal	15
Flying ash	
bituminous	172
sub-bituminous	50
Brown coal	43

1.8. Trace heavy metal accumulation in biota

1.8.1. Accumulation in biofilm

Biofilms consist of microorganisms, which form a coat on solid surfaces in both; aqueous and wet environments [53]. They can be found in surface and ground waters, in drinking water piping, wastewater treatment plants, and in other technical equipment including medical supplies. Biofilms comprise sessile communities of microorganisms, and include bacteria, algae, amoebas, ciliates and fungi in a great variety of compositions. Sunlight favors the growth of photoautotrophic components of biofilms such as algae and cyanobacteria that participate in photosynthesis building biomass from inorganic substances [54]. Biofilms have been used in the same way as other microorganisms, as models in ecotoxicology to estimate the degree of pollution of natural water bodies and the hazard potential of toxic substances. This is possible due to the fact that biofilms play a key role in the ecosystem metabolism, and due to their interaction with toxic substances [55]. In addition, immobile biological elements accumulate pollutants over a long period of time and may thus reveal relevant impacts [54]. A typical image of a biofilm is illustrated in figure 2.

Figure 2 Biofilm attached on a ground surface at sample location (6); Picture taken in June 2012

1.8.2. Accumulation in moss

The “HM in mosses survey” was originally established in 1980 as a joint Danish-Swedish initiative under the leadership of Åke Rühling, Sweden. The idea of using mosses to measure atmospheric HM deposition was developed in 1968 by Rühling and Tylor, and in 1970 by Tyler. Although some baseline data, such as the HM deposition rates, have been calculated from concentrations in mosses in some countries for several years, the “moss-method” is only an additional tool for regulations on a national and international level. The technique of moss analysis therefore provides a surrogate, time-integrated measure of the spatial patterns of HM deposition from the atmosphere in terrestrial systems. Given that mosses have a higher trace element concentration in comparison to rain water, their analysis is simpler, straight forward and less prone to contamination [56]. An aquatic moss is shown below in figure 3.

Figure 3 Common aquatic moss *Fontinalis antipyretica* at sample location (3); Picture taken in May 2013

1.8.3. Accumulation in fish parasites

Due to the interactions of aquatic parasites with their hosts and environment throughout the recent years, aquatic parasites have acquired particular interest from an ecological point of view (see figure 4).

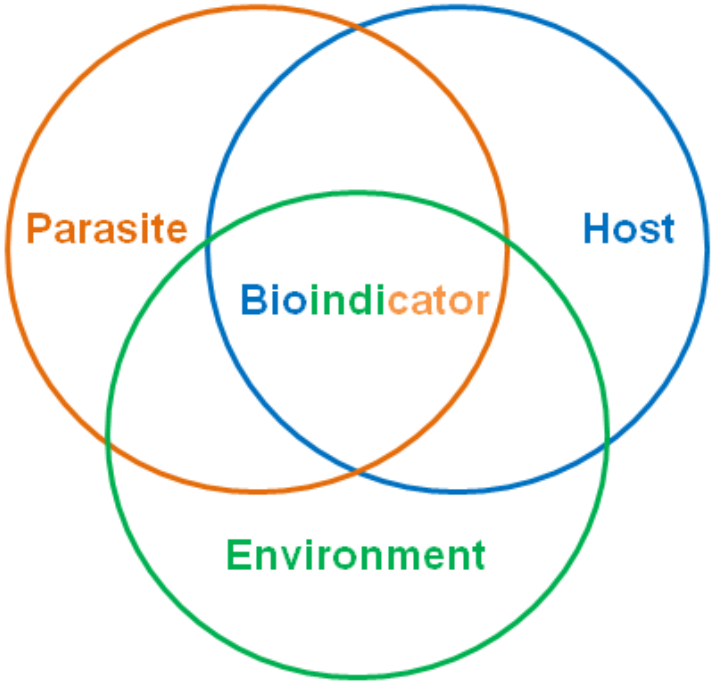

Figure 4 Interactions between host, parasite and environment, redrawn from Sures [57]

Among other factors, the viability and longevity of parasites are dependent on external environmental conditions. This direct impact of the environment on parasite longevity could be used as laboratory bioassays [58]. Parasites can be therefore applied as accumulation indicators. Such organisms provide valuable information about the chemical state of their surroundings through their ability to deposit significant environmental substances within their tissues to levels surpassing the ambient concentrations. In recent years, it has been shown that not only free living organisms, e.g. mussels and crustaceans [59], but also parasites are able to accumulate HM within their tissues to valuable orders of magnitude even higher than those in the host organs or the environment [60].

1.9. Aim and scope of the thesis

Since the year 1991 the quality of Austrian rivers and ground waters have been evaluated and analyzed under a legal system called the Water Quality Monitoring Ordinance. This investigation has been performed by the Federal Ministry for Agriculture and Forestry, the Environment and Water Resources in cooperation with the Federal Environmental Agency and the nine regional government offices. In accordance to the European guidelines, the monitoring of sediments and saprobiological evaluation of water quality is executed once per year. Overall, these evaluations help to conclude whether the analyzed waters are either contaminated or contain a level of different HM such as lead, copper, cadmium, nickel and chromium that surpasses the already established limits. The aim of this study consists on following this federal criteria while collecting HM data from sediments, biofilms, moss, and conducting investigations on tissues specifically enriched with HM, from fishes and their intestinal parasites, when applicable. In this respect, the possible impact of distinct anthropological influences and the natural presence of trace metals in the environment were, of course, considered. Furthermore, all measurements were performed with a brand new instrument, the graphite furnace atomic absorption spectrometer. At the beginning, this instrument was employed to define the limit of detection (LOD) of the investigated HM. The evaluation of various prepared reference materials have been already performed by other entities such as the National Research Council Canada for DORM-3, DOLT-3 and PACS-2 in order to confirm different certified HM values under parameter variation of the analytical instrument, which includes temperature programs, wavelength *et cetera*. In the end, comparisons of HM in different compartments, between the results and the recent report of the Federal Environmental Agency have been done to formulate feasible conclusions about environmental pollution.

2. Materials and Methods

2.1. Atomic Absorption Spectrometry

,,Atomic absorption spectrometry (AAS) is a spectral analytical process for the qualitative verification and quantitative determination of elements with the aid of optical radiation due to free atoms in the gaseous state [61]‘‘

Light sources such as hollow cathode lamps (HCLs) are emitting variant wavelengths that depend on the element to be investigated. Nowadays, a graphite tube is located in the optical pathway to act as an atomization unit. The investigated samples can be atomized, which leads to single excited atoms. Atomization can be achieved with a gas flame with which the solution will be sputtered, through fast heating in an electrical heated graphite tube (GFAAS) within a resistance heating, or with the aid of the hydride technique applied for special investigations.

2.1.1. Setup

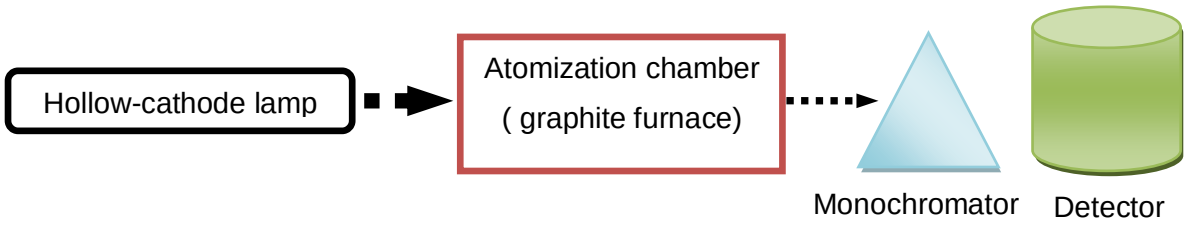

Figure 5 Light pathway within the GFAAS, redrawn from Otto [62]

The light pathway within the GFAAS consists on distinct steps. First, the specific light beam of the investigated element, which is emitted due to a hollow-cathode lamp, goes through the atomization chamber, where the sample is located. Such atomization chamber runs under different temperature programs e.g. drying, pyrolysis and atomization stage. In the last stage of the light pathway, the atomization measurement takes place through the graphite furnace. Indeed, the whole sample will be atomized and remain in the graphite chamber in the form of

vapor. After the original beam decreases as a result of the atomic vapor, the intensity will be measured and it will be compared with the original beam as simply illustrated in figure 5. This whole process leads to the Beer-Lambert law.

2.1.2. Beer-Lambert Law

As a matter of fact, the principle of this measurement is not so complicated. After decreasing the incoming beam in the atomization cloud unit, the intensity will be determined and compared with the non-decreased beam. This relationship is explained through the Beer-Lambert law
(figure 6).

$$A_\lambda = \log \frac{I_0}{I_d}$$

A_λ - Extinction
I_0 - Beam intensity before absorption
I_d - Beam intensity after absorption

Figure 6 Beer-Lambert law redrawn from Otto [62]

In this manner, the amount of projected light through a specific wavelength, which is absorbed through the element to be measured, can be detected. By increasing the analyte concentration in the sample, the decrease of projected light will increase proportionally[62].

2.1.3. Zeeman Correlation

The Zeeman effect was discovered and described for the first time by the Dutch physicist Pieter Zeeman in the year 1896, who shared the Nobel Prize in Physics with Hendrik Antoon Lorentz six years later. The Zeeman correlation describes the splitting-up of a spectral line by applying a magnetic field. It occurs as a result of Absorption and Emission lines. From the three components included in this correlation, π represents the original wavelength λ_0 while σ^+ and σ^- are shifted to higher or lower wavelengths around Δλ. The splitting is proportional to the applied magnetic field strength. Moreover, an optical polarization will take place for the three split up spectral lines as illustrated below (figure 7) [63].

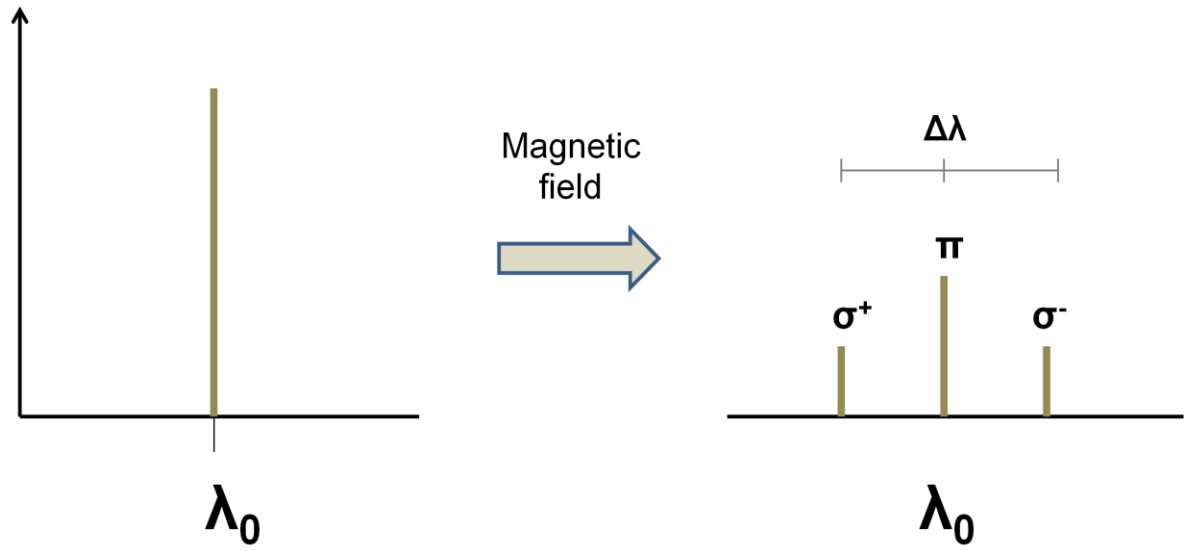

Figure 7 Spectral line splitting by the Zeeman effect obtained after applying a magnetic field, redrawn from Welz [63]

The aim of this technique is to blank out the background signal from the analyte signal. In modern atomic absorption instruments, such as the PinAAcle™ 900Z from PerkinElmer®, it is actually not necessary to use a polarizer. In fact, the total absorption (analyte signal + background signal) will be measured without the application of a magnetic field. After that, the underground signal will be determined by switching on the magnetic field. The right orientation makes the polarizer unnecessary if the magnetic field is set parallel to the beam path. In the end, the instrumentation subtracts the underground signal from the total absorption signal [63].

2.1.4. Graphite Furnace Atomic Absorption Spectrometry (GFAAS)

Due to the fact that the graphite furnace is able to conduct electricity, it will be utilized as an electrical resistor when applying an electrical potential and temperatures above 2500 °C. In order to prevent graphite tube oxidation to take place when conducting a measurement, a constant argon or nitrogen gas flow is required. When measuring, a predetermined sample solution will be transferred with a plastic tip into the graphite furnace through a micro hole, which is located on top of the furnace, as illustrated in figure 8.

Figure 8 Transversely-heated graphite atomizer (THGA)

Another advantage of this technique is represented by the small amounts of liquid sample (5–50 µL) that are required [5]. The program runs through many heating steps. The temperature program mostly depends on the investigated element and the chemical condition of the liquid sample. In addition, the sample will be measured depending on the kind of graphite furnace system, e.g. transversely-heated graphite atomization or longitudinally heated graphite atomization unit. In general, the pyrolysis temperatures are around 200 °C in a transversely heated system and the atomization temperatures could be 400 °C less than the longitudinally heated system. The disadvantage of the longitudinal system is the lower precision during the measurement as a consequence of an occurring temperature gradient. In that sense, the THGA system is much more precise.
The basic settings of a temperature program are:

Drying 1: The furnace will be heated up to 130 °C for around 30 seconds in order to minimize and dry the sample.

Drying 2: If necessary, an additional drying sequence can be selected for a complete drying.

Pyrolysis: Depending on the element, the temperature range is usually between 400 °C and 1500 °C. This step is necessary to eliminate any remaining organic compounds.

Atomization: The temperature setup is element specific and rises up to 2400 °C. The sample will be atomized for 5 seconds.

Clean-out: Once the analysis took place, the graphite tube will be heated up to 2450 °C or 2800 °C, depending on the heating system, to eliminate any possible remaining parts of the sample.

2.1.5. Modifier

In the GFAAS chemical modifiers are mostly used for the reduction or elimination of vaporizations or gas phase disturbances. The modifier will be inserted in the graphite furnace together with the sample solution. In addition, the modifier transfers the analyte in a less volatile state, so that higher pyrolysis temperatures could be applied or in order to eliminate matrix substances in an easier manner. An ammonium nitrate modifier will be for instance employed when investigating copper in seawater to avoid disturbances with the nonvolatile sodium chloride, as illustrated in figure 9.

$$NaCl + NH_4NO_3 \rightarrow NaNO_3 + NH_4Cl$$

Figure 9 Transformation from volatile to nonvolatile substances [63]

The nonvolatile sodium chloride (melting point 801 °C, boiling point 1413 °C) forms sodium nitrate, which decomposes at 380 °C, and ammonium chloride that sublimates at 335 °C. The remaining ammonium nitrate is already decomposing above 210 °C [63].

2.2. Sampling locations

The original Wienfluss samples were facilitated by Daniel Seethaler, who collected them for his master thesis (2013). These included sediment, biofilm, moss and fish. The remaining samples were obtained from Christopher Braunsteiner, who gathered them for his master thesis as well (2010). Such samples included sediment, biofilm, moss, fish and fish parasites. Figure 10 represents the sample locations in the Wienfluss (table 6) and in the Schwechat River (table 7) along with the exact positions in which they were taken.

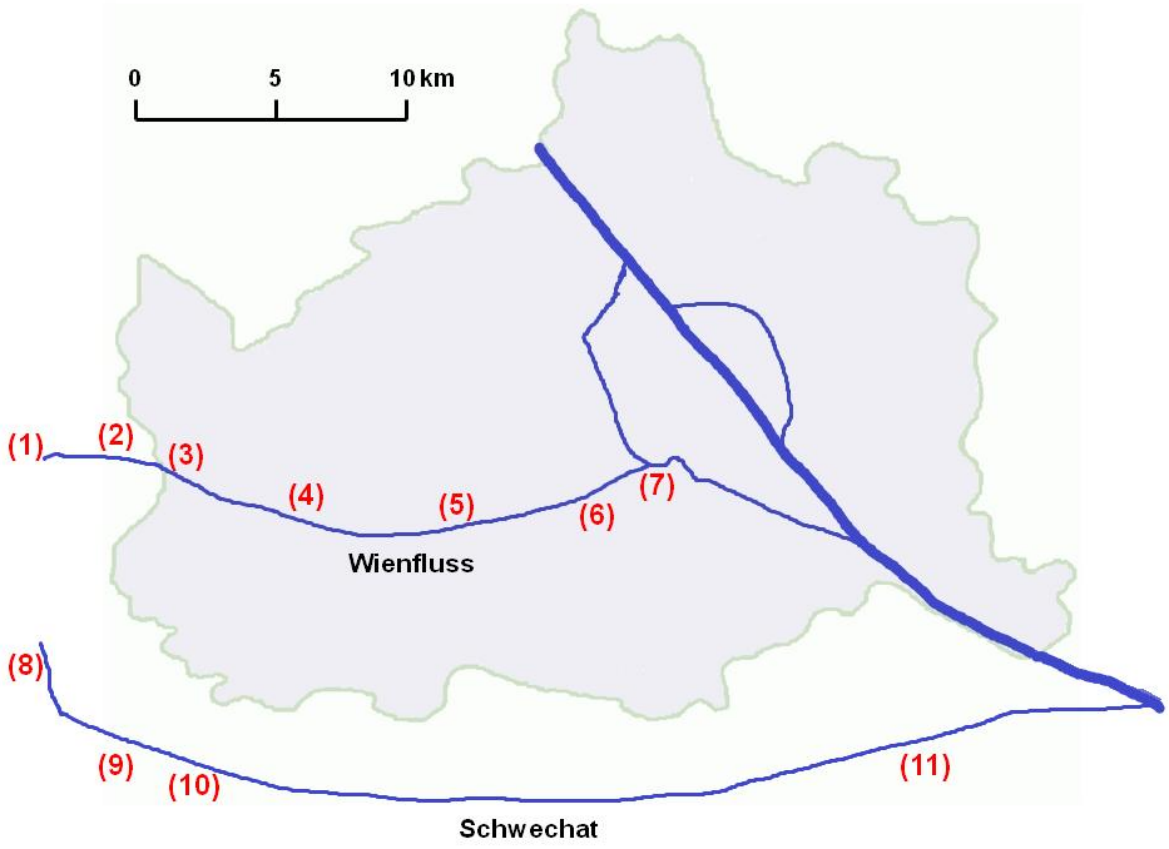

Figure 10 Sampling locations in the Wienfluss and Schwechat River. The numbers are explained in the tables below.

Table 6 Sampling locations in the Wienfluss

Location	Coordinates
(1) Wienerwaldsee	48° 11’ 6,75’’ N; 16° 7’ 27,32’’ E
(2) Purkersdorf	48° 12’ 22,31’’ N; 16° 11’ 28,41’’ E
(3) Bauhaus	48° 11’ 58,42’’ N; 16° 15’ 15,63’’ E
(4) Hietzing	48° 11’ 19,95’’ N; 16° 17’ 56,85’’ E
(5) Pilgram Bridge	48° 11’ 35,06’’ N; 16° 21’ 15,29’’ E
(6) Stadtpark	48° 12’ 23,28’’ N; 16° 22’ 55,89’’ E
(7) Danube Canal	48° 12’ 44,42’’ N; 16° 23’ 11,09’’ E

Table 7 Sampling locations in the Schwechat River

Location	Coordinates
(8) Agsbach	48° 06’ 53’’ N; 16° 00’ 53’’ E
(9) Helenental	48° 00’ 49’’ N; 16° 10’ 15’’ E
(10) Baden	47° 59’ 52’’ N; 16° 15’ 26’’ E
(11) Zwölfaxing	48° 06’ 45’’ N; 16° 27’ 32’’ E

2.3. Sampling

In the month of October, one group of the samples to be analyzed was collected from determined locations along the Wienfluss. The other group of samples was facilitated by Daniel Seethaler, which he had obtained from the beginning of September until the beginning of October. The investigations of the HM content for this environmental research were performed with the aid of the GFAAS. In October 2012 we received 12 fish that included two species, chub n=9 (*Leuciscus cephalus*) and perch n=3 (*Perca fluviatilis*). These were provided by Werner Leithner. The surficial sediments were collected with a plastic spoon and inserted in small polythene tubes. Moss samples were taken in areas in which they were available. Moss was transferred with a plastic pincette in small polythene tubes, which were also filled up with river water. Biofilm was taken where available e.g. from the surface of stones, and it was as well transferred in small polythene tubes with river water. For a fast transfer the samples were transported from the Wienfluss with the aid of a vehicle straight to the laboratory. In addition, all samples were inserted in cooling bags during their transportation in order to cool them.

2.4. Analysis

2.4.1. Sampling preparation

The chemical sampling preparations were performed by Daniel Seethaler. These included drying, ashing and microwave assisted acid digestion of the sediment, biofilm and moss samples. The fish samples from Purkersdorf were prepared by Franz Jirsa, Daniel Seethaler and myself. Prior to the investigation, Franz Jirsa showed us how to properly dissect the distinct fish tissues and samples of ventral muscle, as well as liver were obtained. These samples were acid digested as well. Samples from the Schwechat River, which had been acid-digested by Christopher Braunsteiner for his master thesis, consisting of sediment, biofilm, moss, fish and parasitic worm samples were also included in the analyses for HM content.

2.4.2. Microwave digestion

Acid digestion was done in a microwave digestion system MARS express (CEM Corp.). The samples were weighed, and 9 mL of 35 % nitric acid (TraceSELECT® by FLUKA) was added. Additionally, one mL of 30 % hydrogen peroxide (TraceSELECT® by FLUKA) was added to the fish samples. In order to achieve a complete digestion, a gradual increase of the temperature was performed. The temperature reached 200 °C and stayed like that for 15 min. It then followed a cooling down phase. After cooling down to room temperature, the digestion tubes were carefully opened and the solution was transferred to volumetric flasks in which they were filled up to 15 mL with $H_2O_{bidest.}$

2.4.3. Instrumentation

All HM measurements were executed using a PerkinElmer® PinAAcle™ 900Z atomic absorption spectrometer set with the WinLab32™ software that ran under Microsoft® Windows™ 7.

The PinAAcle™ 900Z is a longitudinal Zeeman system with a double-beam design for fast start-up and exceptional long-term stability. The cutting-edge fiber optics maximize light input to achieve improved detection limits, and the TubeView™ color furnace camera allows easier auto sampler tip alignment and sample dispensing, as well as the drying and pyrolysis monitoring during the analysis for a smooth method development. The use of a transversely heated graphite atomizer (THGA) leads to homogeneous temperatures across the entire length of the tube [64]. The instrumental conditions are represented in table 8. In addition, figure 11 shows the analytical instrument with which all HM analysis were performed. To begin with the analysis, the argon gas bottle was opened and the pressure regulator was adjusted to 6 bar. Then, the instrument was turned on and the WinLab32™ software was executed. The element to be analyzed was selected with the aid of the computer software. After selecting the element, the hollow cathode lamp (HCL) had to warm up for 15 min. before starting the calibration or analysis. A standard calibration was performed for each HM within distinct calibration ranges depending on the HM as shown in figures 13–17.

Figure 11 PinAAcle™ 900Z (PerkinElmer®) Institute of Inorganic Chemistry University of Vienna

The ideal wavelengths and slit gaps are automatically given by the program for each element. Each sample was measured three times and the mean value was as well automatically calculated by to the program.

Table 8 Used instrumental setup parameters for all HM analysis

Analyte	Wavelength (nm)	Slit (nm)
Pb	283.3	0.7
Cu	324.8	0.7
Cd	228.8	0.7
Ni	341.5	0.7
Cr	357.9	0.7

2.5. Limit of detection (LOD) for heavy metals

A very important factor for evaluating an analytical technique or method is the LOD. The LOD is defined as the smallest amount of substance that can be distinguished from the blank measurement and of which detection is achievable. A traditional and typical approach to estimate the LOD consists of measuring replicates of blank samples, determining the mean value and the standard deviation (SD), and calculating the LOD. Figure 12 is representing the equation used for that calculation [63].

$$LOD = \dot{x}_B + nSD_B$$

$\dot{x}_B$ = Mean of blank values
SD_B= Standard deviation of blank values

Figure 12 The LOD equation from Welz [63]

2.6. Certified reference material DOLT-3, DORM-3 and PACS-2

The exact determination of various trace HM concentrations is possible with certified material. For this research a dogfish liver certified reference material (DOLT-3) obtained from the National Research Council Canada (NRCC) was consulted for Pb, Cu, Cd and Ni. Fish protein certified reference material (DORM-3) also from NRCC was used for the determination of Cr, and a marine sediment reference material (PACS-2), from NRCC as well was employed for all trace HM to compare established HM trace values, such as those for Pb, Cu, Cd, Ni and Cr (table 9), with the measured values.

Table 9 Certified reference material [65] values given by the NRCC(mg/kg d.w.)

Trace HM	DOLT-3 ; DORM-3*	PACS-2
Pb	0.32 ± 0.05	183 ± 8
Cu	31.2 ± 1.0	310 ± 12
Cd	19.4 ± 0.6	2.11 ± 0.15
Ni	2.72 ± 0.35	39.5 ± 2.3
Cr	1.89* ± 0.17	90.7 ± 4.6

Reference material was prepared exactly as described above for other samples. It was as well required to run the cloudy liquid through a filter (0.2 µm, Teflon®) in order to avoid measurement errors. In addition, in the case of copper and cadmium; a 1:10 dilution and a 1:100 dilution were performed, respectively. Afterwards, the calibration ranges were obtained, and the spectroscopic trace material analysis was performed.

3. Results

3.1. LOD

3.1.1. LOD for Pb

Experimental determination:

The absorbance measurements of six times the blank values (2 % nitric acid) + the Modifier ($NH_4H_2PO_4$+$Mg(NO_3)_2$) were performed to define and compute the LOD. Overall, the alignment tip from the auto sampler always took 20 µL + 5 µL of modifier, if a modifier was in use. The mean blank value was defined with -0.0002. The SD was calculated as 0.0002 and has been calculated 3 times to the blank measurement. Therefore, the LOD was determined at an absorbance value of 0.0004. The calibration was later performed within the range of 0–50 µg/L. The calculated calibration curve is shown in figure 13.

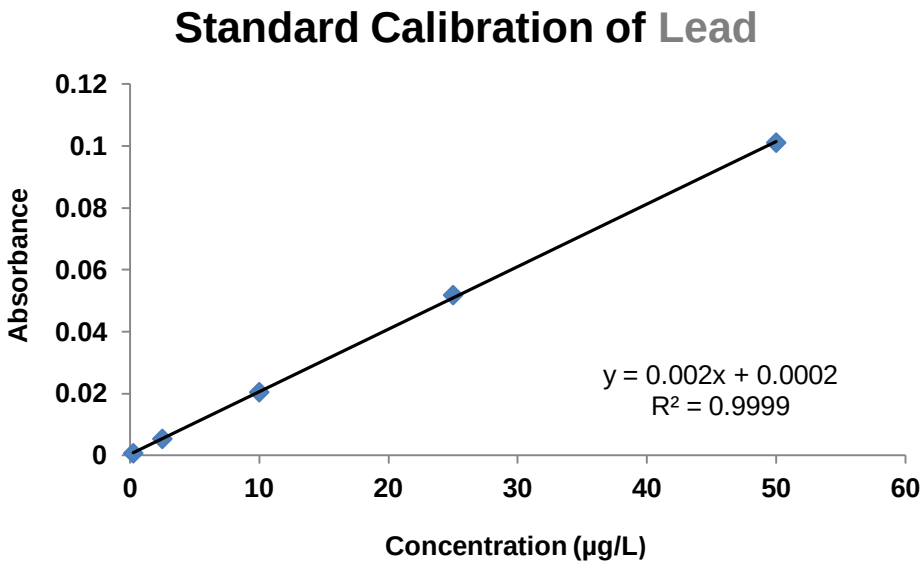

Figure 13 Pb standard calibration

The resulting LOD was calculated to be 0.1 µg/L-Pb

3.1.2. LOD for Cu

Experimental determination:

The absorbance measurements of six times the blank values (2 % nitric acid) + the Modifier ($Pd+Mg(NO_3)_2$) were performed in order to define and compute the LOD .The mean blank value was defined as 0.0014666. In addition, the SD was set with a value of 0.0000516 and has been calculated 3 times to the blank measurement. Finally, the LOD was determined with an absorbance value of 0.00162. The standard calibration of the standard solutions within the range of 0–50 µg/L + the modifier was performed afterwards (figure 14).

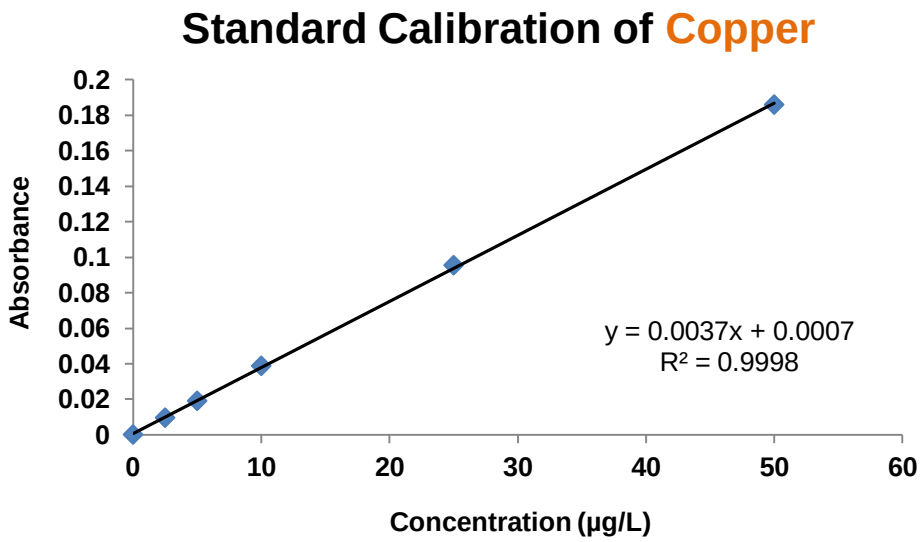

Figure 14 Cu standard calibration

The resulting LOD was calculated to be 0.2 µg/L.

3.1.3. LOD for Cd

Experimental determination:

The absorbance measurements of six times the blank values (2 % nitric acid) + the Modifier ($NH_4H_2PO_4$+$Mg(NO_3)_2$) were performed to define and compute the LOD .The mean blank value was defined as -0.005433. In addition, the SD was set with a value of 0.00143 and has been calculated 6 times to the blank measurement. Finally, the LOD was determined with an absorbance value of 0.00315. The standard calibration of the standard solutions within the range of 0–2.5 µg/L + the modifier was later performed (figure 15).

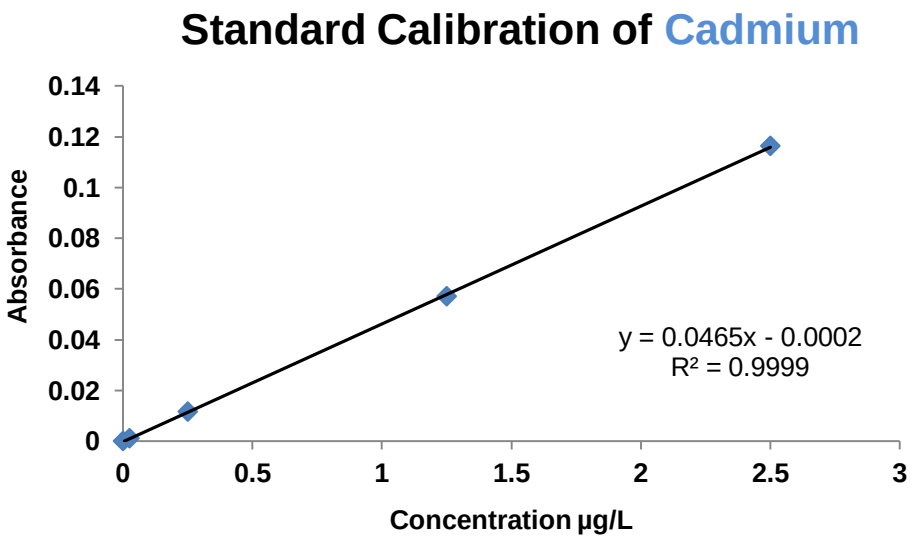

Figure 15 Cd standard calibration

The resulting LOD was calculated to be 0.07 µg/L.

3.1.4. LOD for Ni

Experimental determination:

In the case of nickel, the recommended wavelength of 232.0 nm was not the preferred one because the standard calibration did not perform accurately. This is the reason why the nickel determination has been executed with an alternative non sensitive wavelength. The absorbance measurements of three blank values (2 % nitric acid) were run, without the use of a modifier, to define and compute the LOD. The mean blank value was defined with 0.0003. In addition, the SD was set to a value of 0.0001 and has been calculated 3 times to the blank measurement. Finally, the LOD has been determined with an absorbance value of 0.0006. The standard calibration of the standard solutions within the range of 0–50 µg/L were performed afterwards (figure 16).

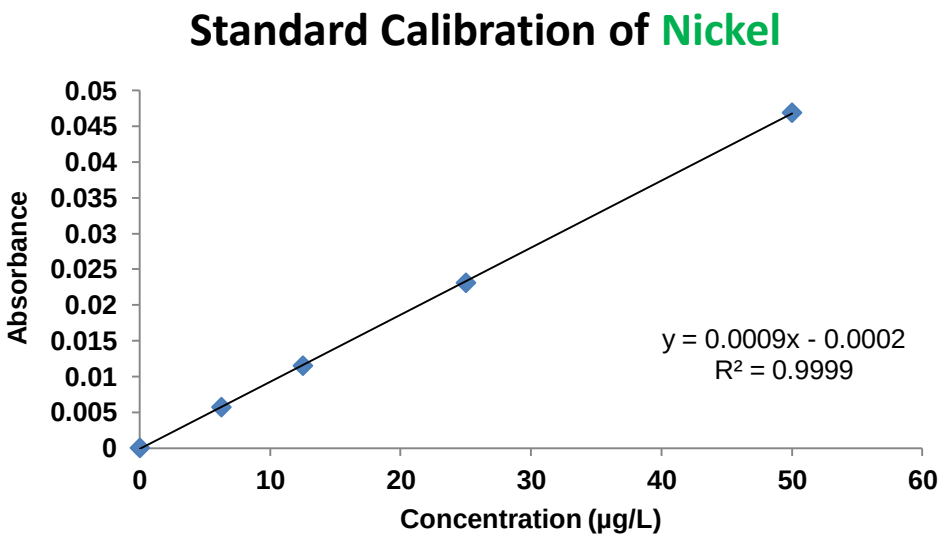

Figure 16 Ni standard calibration

The resulting LOD was calculated to be 0.8 µg/L.

3.1.5. LOD for Cr

Experimental determination:

The absorbance measurements of six blank values (2 % nitric acid) were performed, without using a modifier, to define and compute the LOD. The mean blank value was then defined to be 0.001067. In addition, the SD was set to a value of 0.000103 and was calculated 3 times to the blank measurement. Finally, the LOD was determined with an absorbance value of 0.00140. The standard calibration of the standard solutions within the range of 0–10 µg/L were later performed (figure 17).

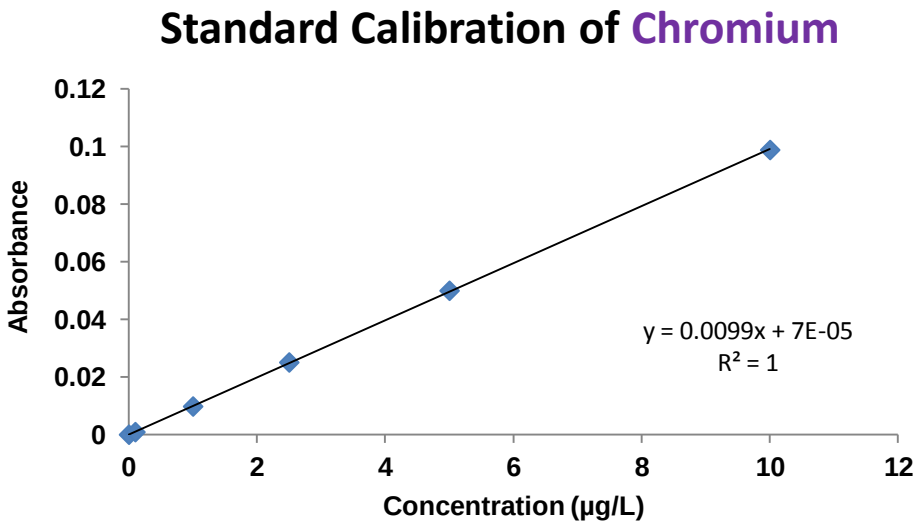

Figure 17 Cr standard calibration

The resulting LOD was calculated to be 0.1 µg/L.

3.2. Recovery rates for DOLT-3, DORM-3 and PACS-2

Experimental determination of DOLT-3/DORM-3:

The achieved values are represented in table 10.

Table 10 Element concentrations in DOLT-3 and DORM-3* (certified by NRCC) and as detected with GFAAS, (mean ± SD of three measurements), and mean accuracy

Element	NRCC (µg/g)	GFAAS (µg/g)	Accuracy (%)
Pb	0.32 (±0.05)	0.33 (±0.010)	104.2
Cu	31.2 (±1.0)	31.43 (±0.305)	100.8
Cd	19.4 (±0.6)	19.68 (±0.542)	101.5
Ni	2.72 (±0.35)	3.05 (±0.181)	108.7
Cr	1.89* (±0.17)	1.88 (±0.11)	99.3

Experimental determination of PACS-2:

The obtained values are represented in table 11.

Table 11 Element concentrations in PACS-2 (certified by NRCC) and as detected with GFAAS, (mean ± SD of three measurements), and mean accuracy

Element	NRCC (µg/g)	GFAAS (µg/g)	Accuracy (%)
Pb	183 (±8)	173 (±3.6)	94.3
Cu	310 (±12)	315 (±25)	101.5
Cd	2.11 (±0.15)	2.28 (±0.16)	108.1
Ni	39.5 (±2.3)	38.9 (±1.4)	98.5
Cr	90.7 (±4.6)	99.5 (±3.8)	109.7

3.3. Sediment

3.3.1. Lead content

For the determination of lead, all sediment samples had to be diluted within 1:10 to 1:10000 to allow an accurate measurement in the calibration range. The dilutions were made by adding about 2 % nitric acid in the right ratio.

Wienfluss:

In the Wienfluss the lead values varied between 15 and 3620 µg/g (d.w.). Figure 18 is representing the mean values + the 95 % confidence intervals.

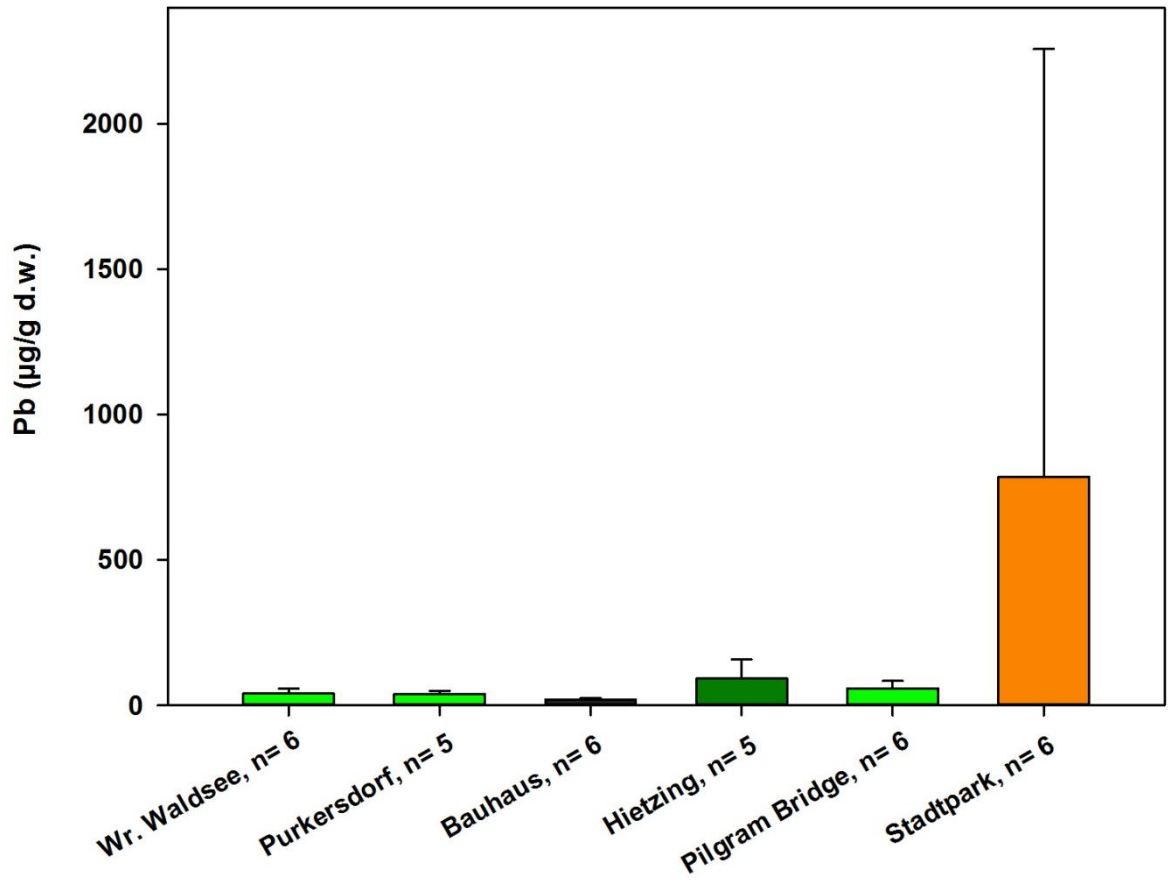

Figure 18 Lead content in sediment of the Wienfluss

Schwechat River:

In the Schwechat River, the lead values varied between 7 and 33 µg/g (d.w.). Figure 19 is representing the mean values + the 95 % confidence intervals.

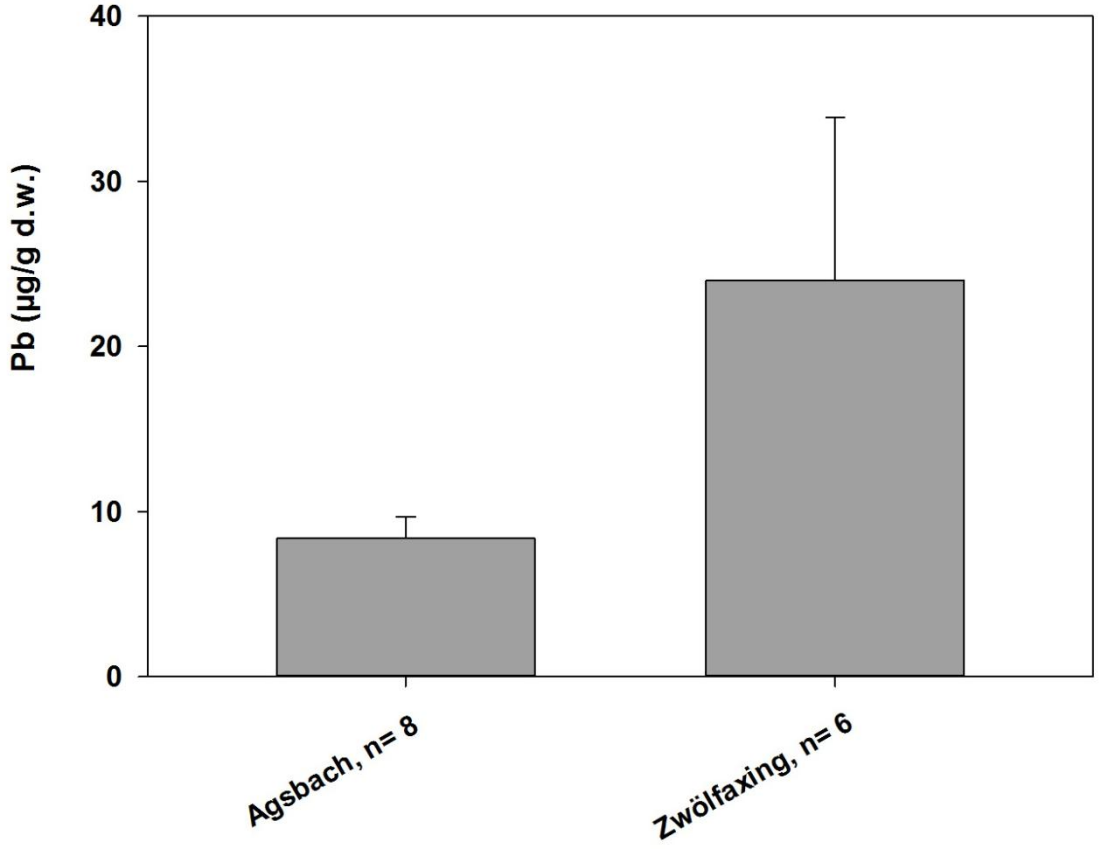

Figure 19 Lead content in sediment of the Schwechat River

3.3.2. Copper content

For the determination of copper, all sediment samples had to be diluted within 1:10 to 1:1000. The dilutions were performed with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the copper values varied between 24 and 517 µg/g (d.w.). Figure 20 is representing the mean values + the 95 % confidence intervals.

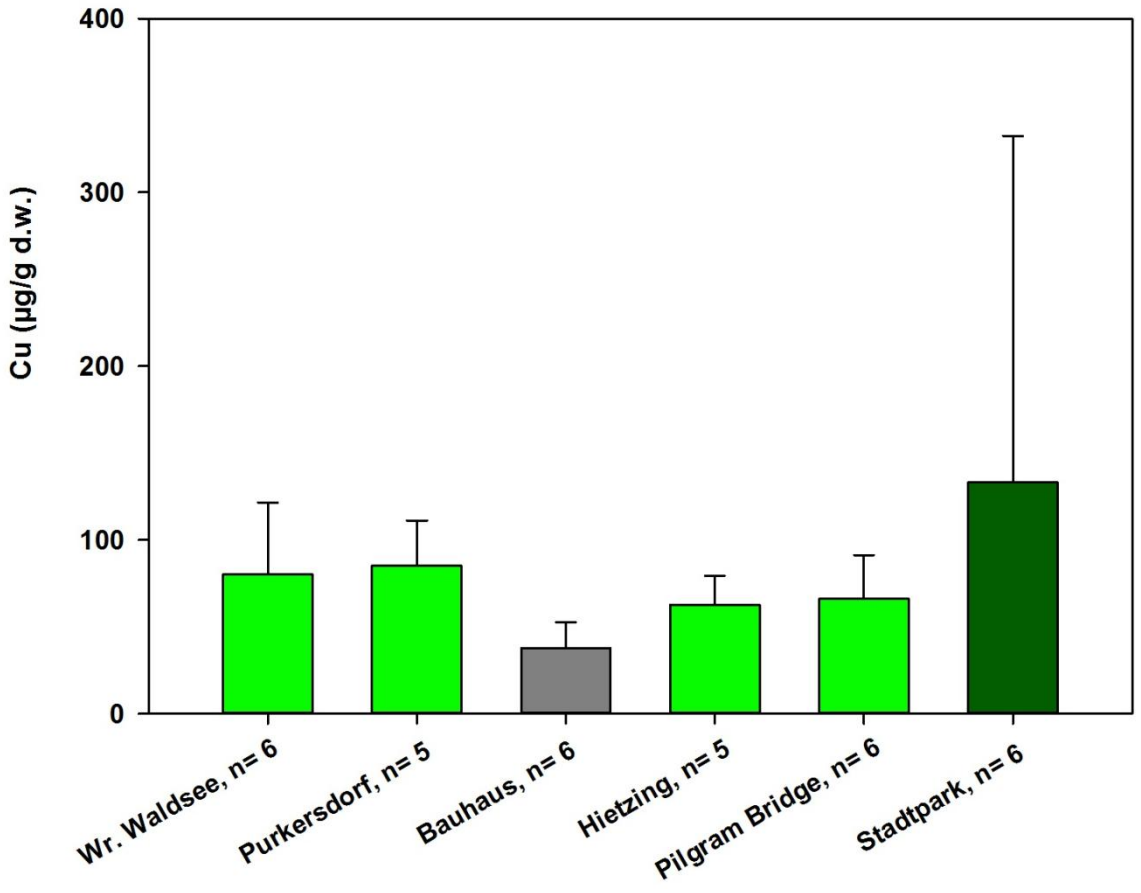

Figure 20 Copper content in sediment of the Wienfluss

Schwechat River:

In the Schwechat River, the copper values varied between 11 and 76 µg/g (d.w.). Figure 21 is representing the mean values + the 95 % confidence intervals.

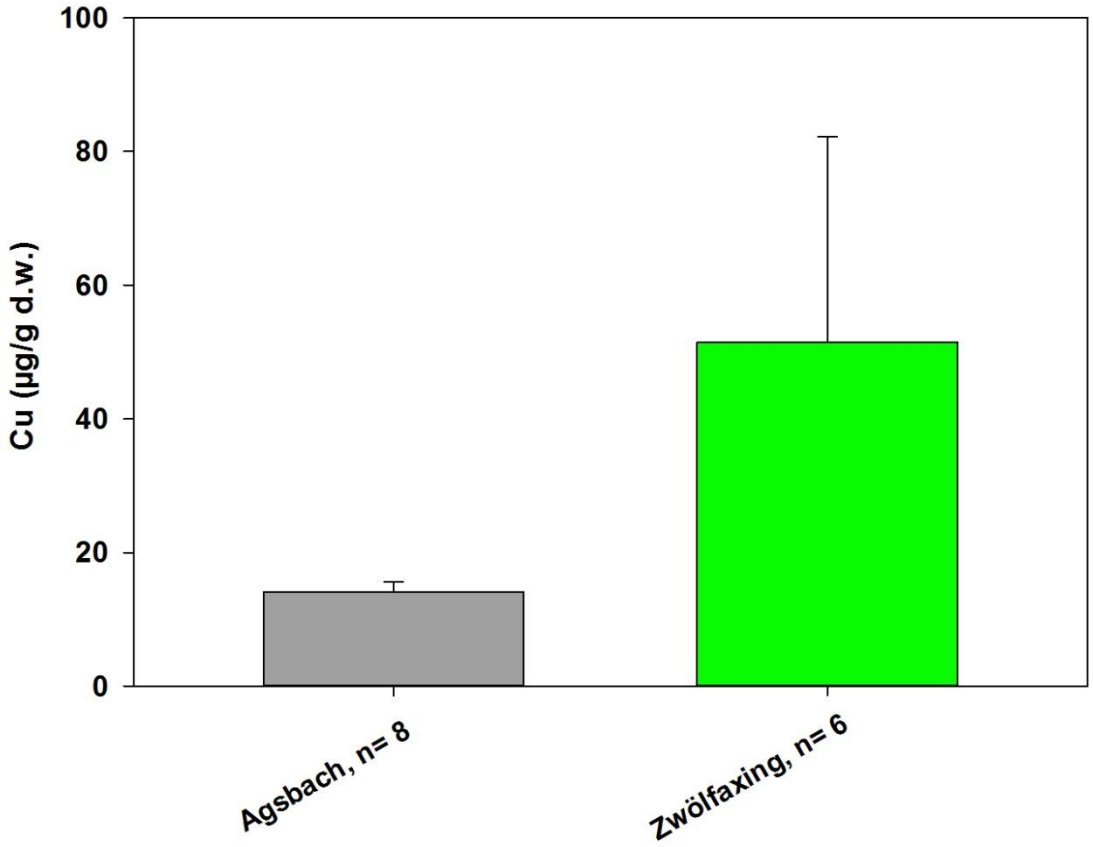

Figure 21 Copper content in sediment of the Schwechat River

3.3.3. Cadmium content

For the determination of cadmium, all sediment samples had to be diluted within 1:10 to 1:100. The dilutions were made with about 2 % nitric acid.

Wienfluss:

In the Wienfluss the cadmium values varied between 0.1 and 1.4 µg/g (d.w.). Figure 22 is representing the mean values + the 95 % confidence intervals.

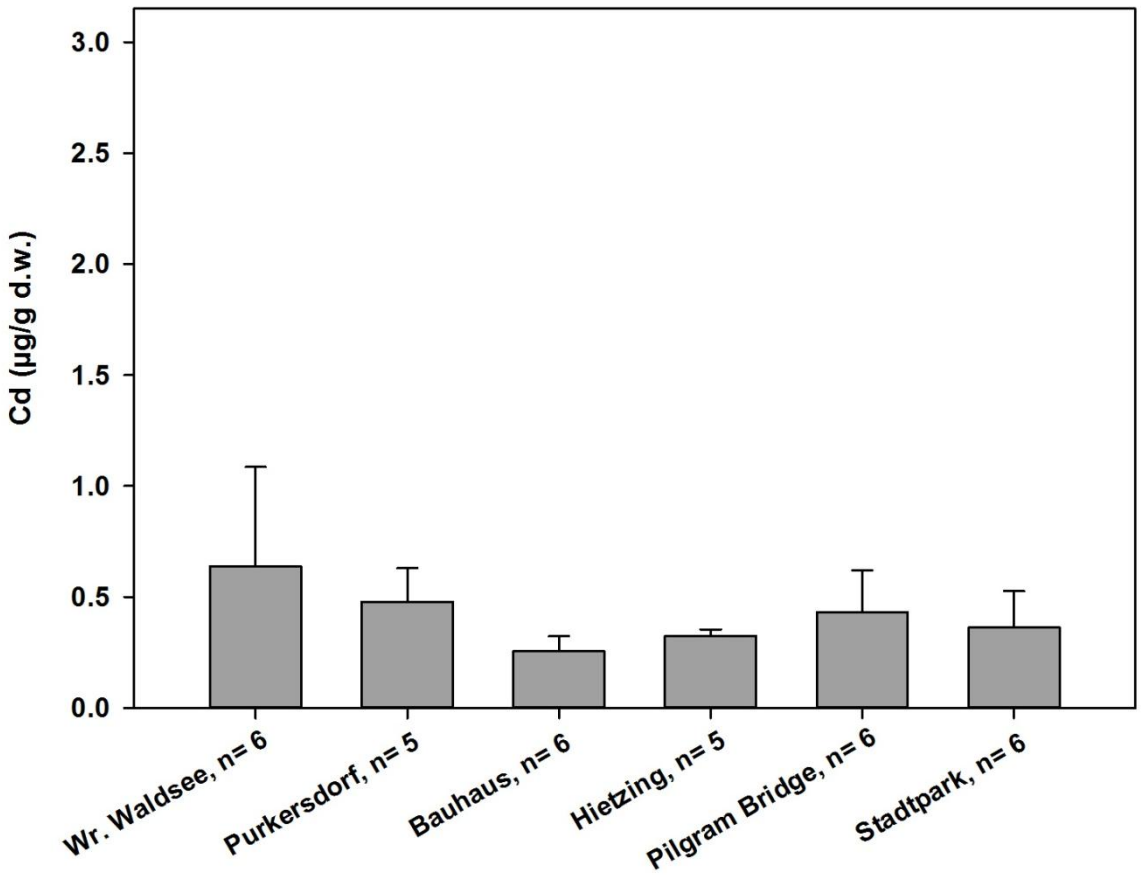

Figure 22 Cadmium content in sediment of the Wienfluss

Schwechat River:

In the Schwechat River, the cadmium values varied between 0.06 and 0.41 µg/g (d.w.). Figure 23 is representing the mean values + the 95 % confidence intervals.

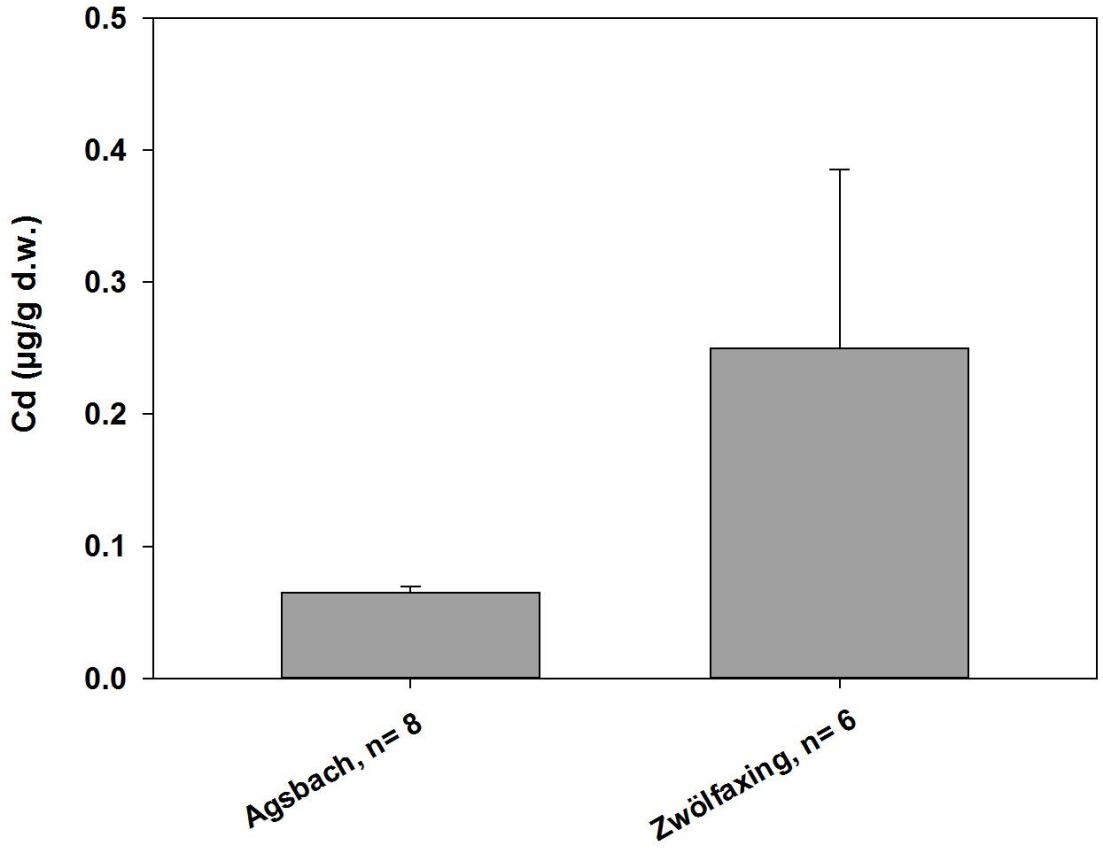

Figure 23 Cadmium content in sediment of the Schwechat River

3.3.4. Nickel content

For the determination of nickel, all sediment samples had to be diluted within 1:10 to 1:100. The dilutions have been made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the nickel values varied between 7 and 57 µg/g (d.w.). Figure 24 is representing the mean values + the 95 % confidence intervals.

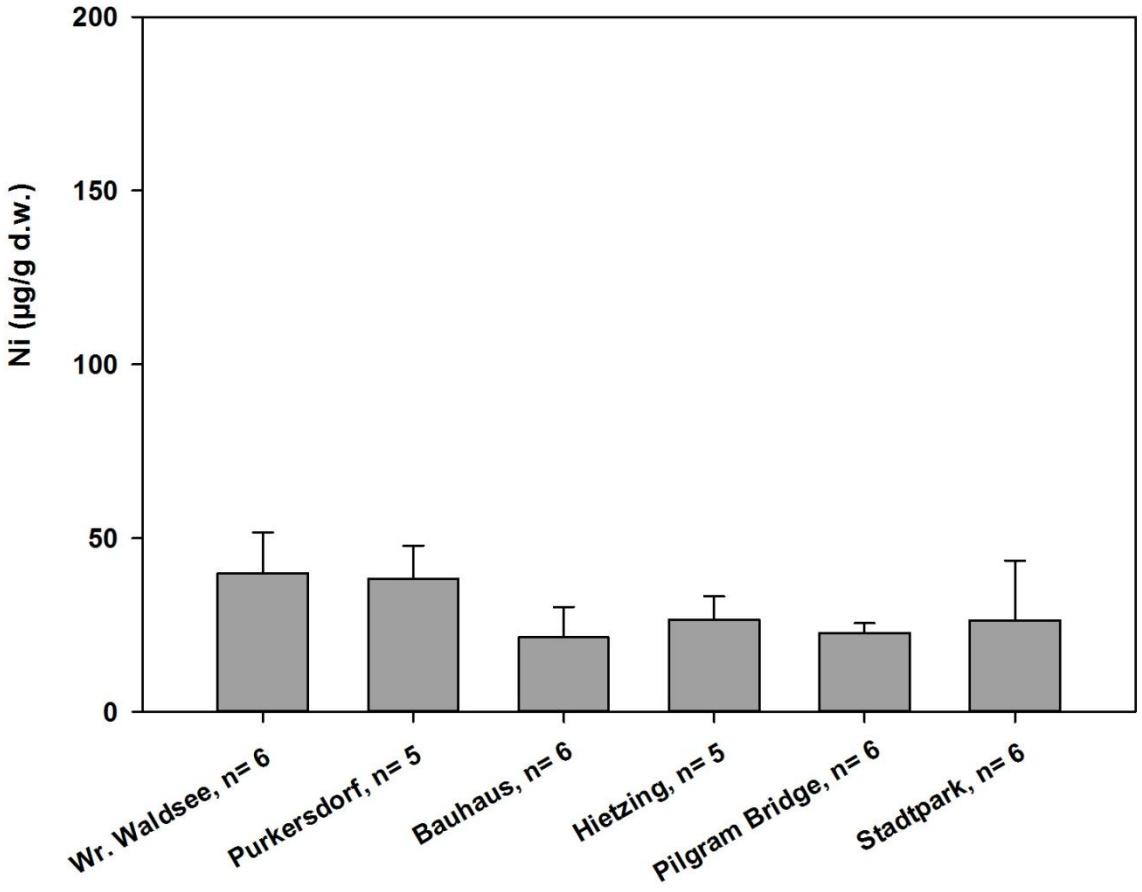

Figure 24 Nickel content in sediment of the Wienfluss

Schwechat River:

In the Schwechat River, the nickel values varied between 0.06 and 0.41 µg/g (d.w.). Figure 25 is representing the mean values + the 95 % confidence intervals..

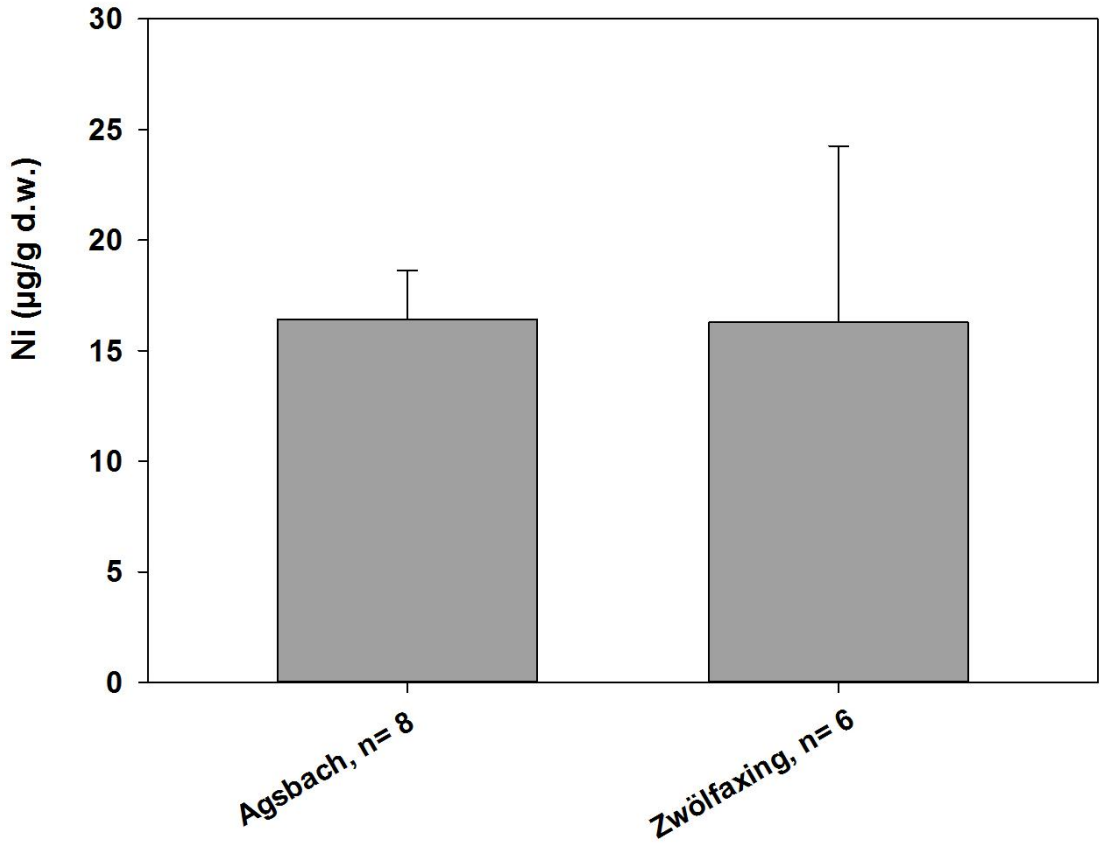

Figure 25 Nickel content in sediment of the Schwechat River

3.3.5. Chromium content

For the determination of chromium, all sediment samples had to be diluted within 1:100 to 1:1000. The dilutions were made with about 2 % nitric acid.

Wienfluss:

In the Wienfluss, the chromium values varied between 19 and 161 µg/g (d.w.). Figure 26 is representing the mean values + the 95 % confidence intervals.

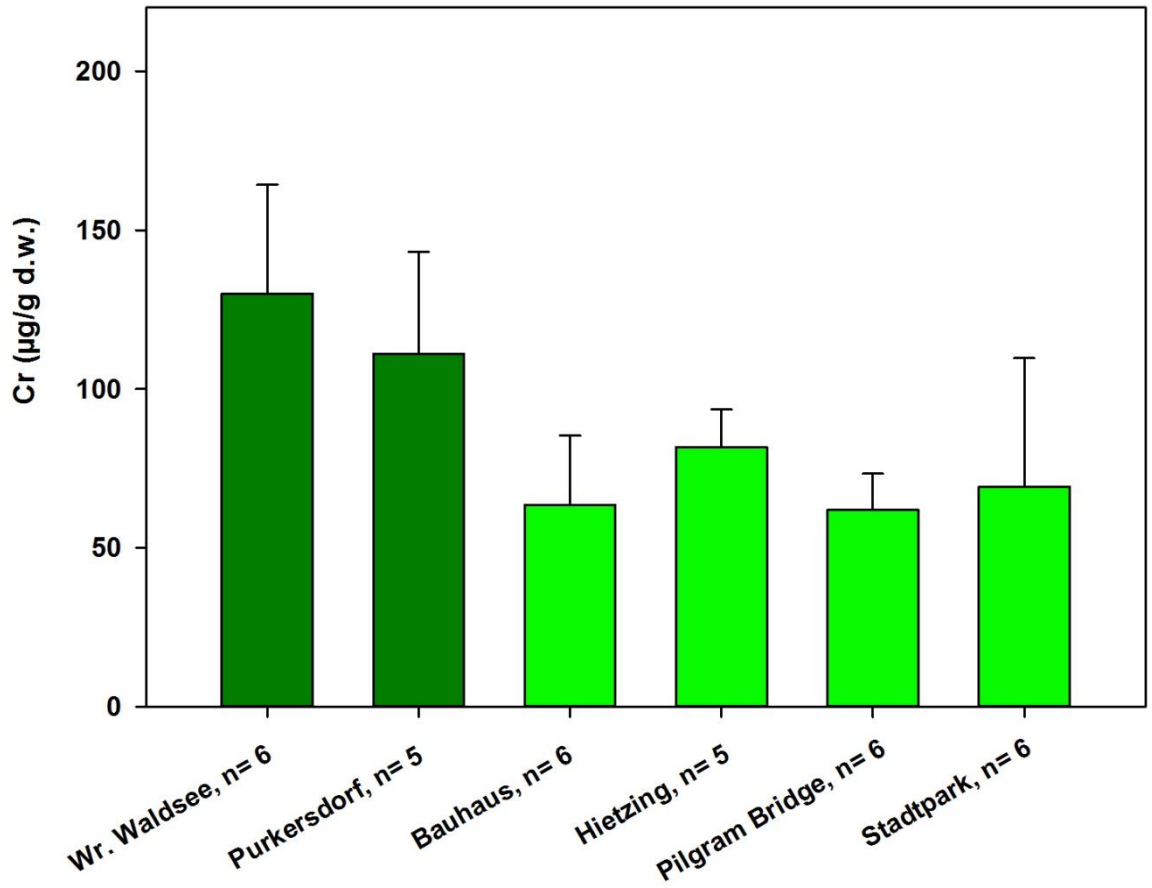

Figure 26 Chromium content in sediment of the Wienfluss

Schwechat River:

In the Schwechat River, the chromium values varied between 15 and 51 µg/g (d.w.). Figure 27 is representing the mean values + the 95 % confidence intervals.

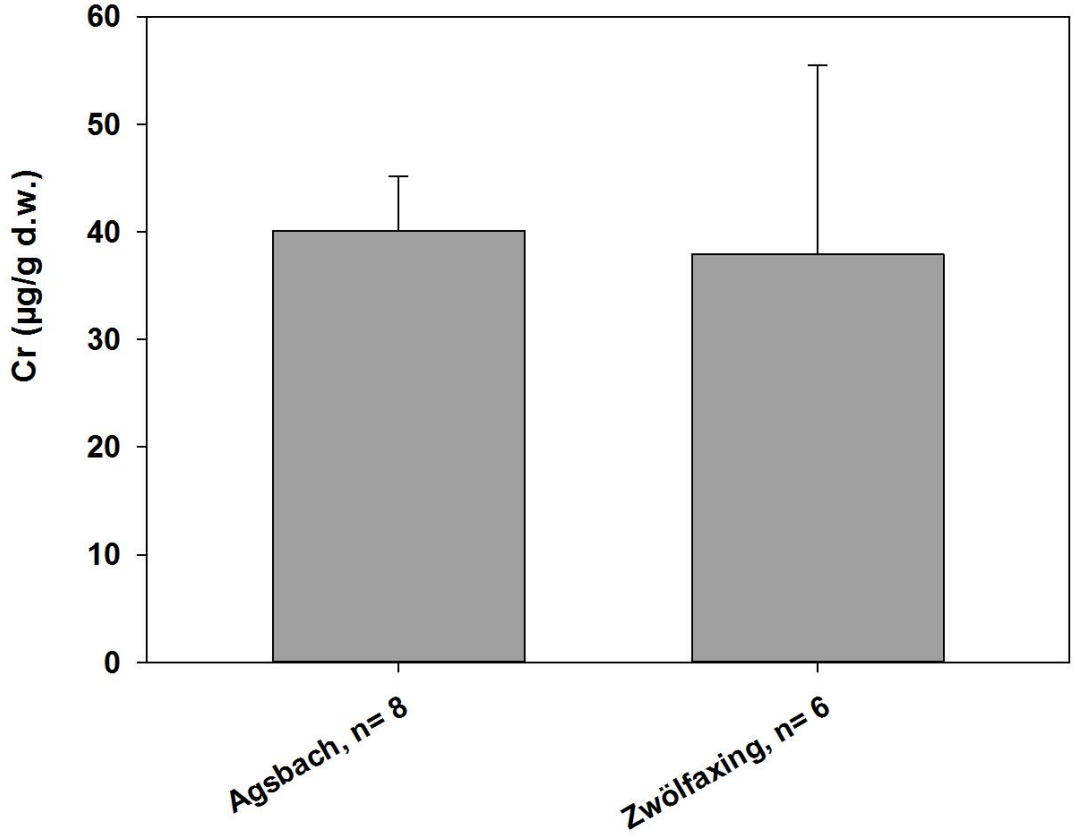

Figure 27 Chromium content in sediment of the Schwechat River

3.4. Biofilm

3.4.1. Lead content

For the determination of lead, all biofilm samples had to be diluted within 0 to 1:1000. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the lead values varied between 7 and 861 µg/g (d.w.). Figure 28 is showing the mean values + the 95 % confidence intervals.

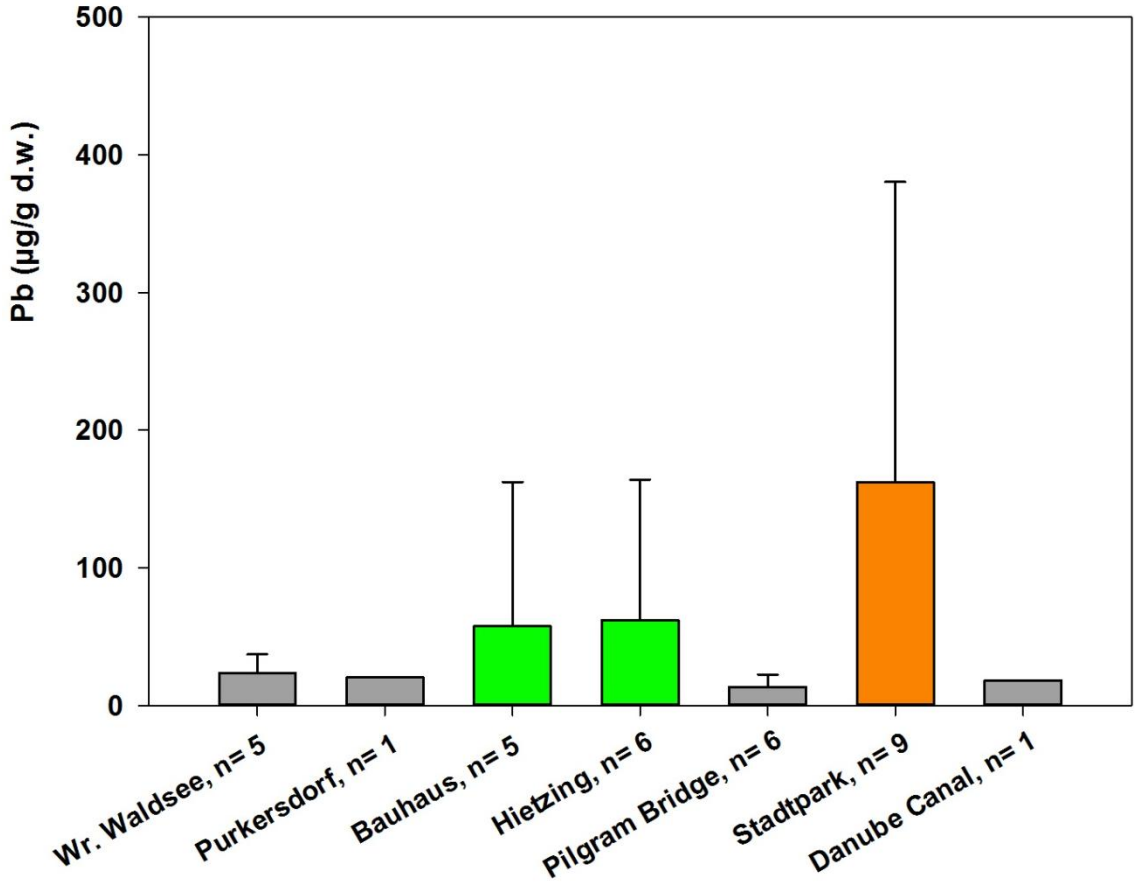

Figure 28 Lead content in biofilm of the Wienfluss

Schwechat River:

In the Schwechat River, the lead values varied between 4 and 18 µg/g (d.w.). Figure 29 is representing the mean values.

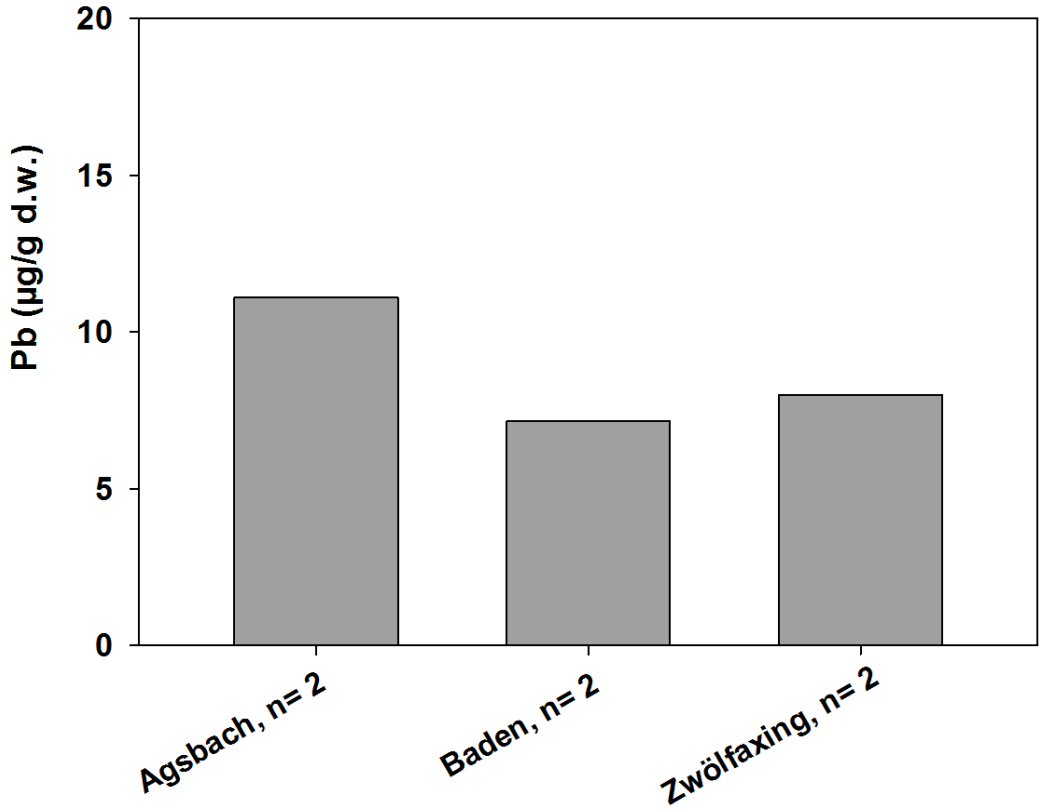

Figure 29 Lead content in biofilm of the Schwechat River

3.4.2. Copper content

For the determination of copper, all biofilm samples had to be diluted within 1:10 to 1:1000. The dilutions were made with about 2 % nitric acid.

Wienfluss:

In the Wienfluss, the copper values varied between 17 and 1752 µg/g (d.w.). Figure 30 is showing the mean values + the 95 % confidence intervals.

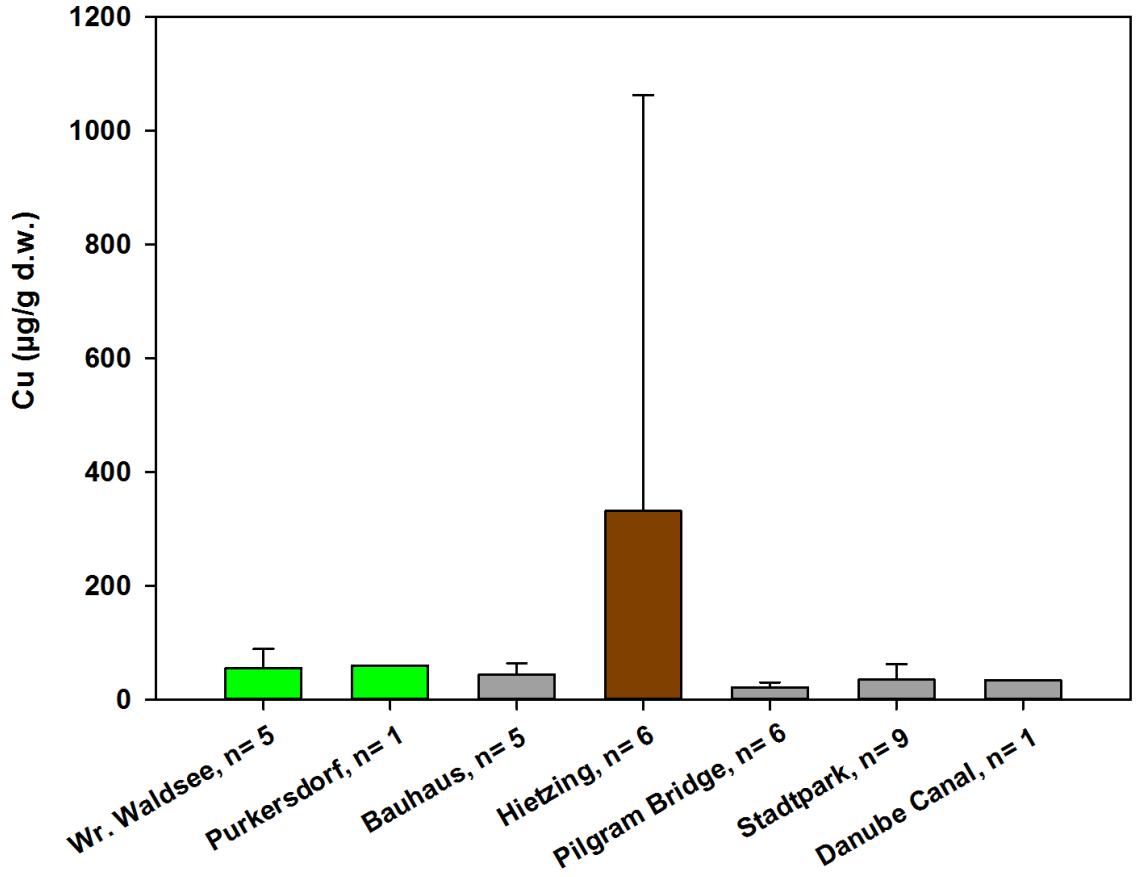

Figure 30 Copper content in biofilm of the Wienfluss

Schwechat River:

In the Schwechat River, the copper values varied between 14 and 38 µg/g (d.w.). Figure 31 is representing the mean values.

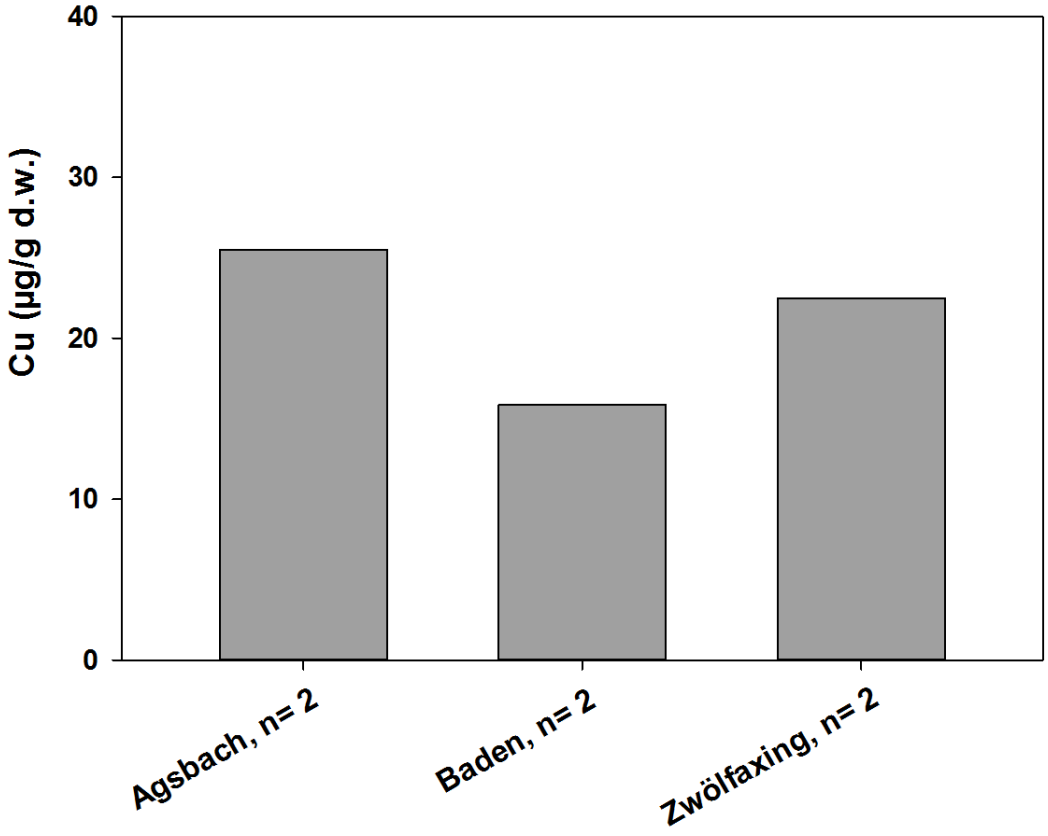

Figure 31 Copper content in biofilm of the Schwechat River

3.4.3. Cadmium content

For the determination of cadmium, all biofilm samples had to be diluted 1:10. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the cadmium values varied between 0.13 and 0.87 µg/g (d.w.). Figure 32 is showing the mean values + the 95 % confidence intervals.

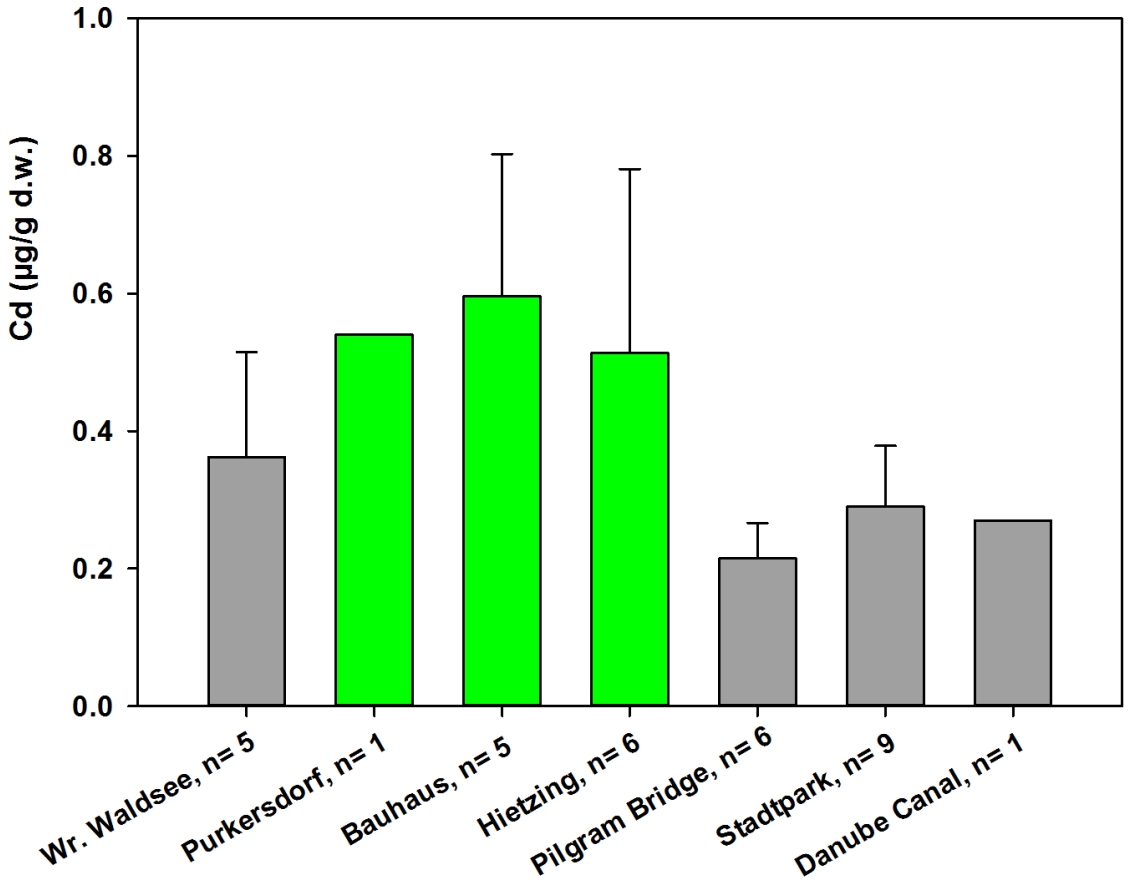

Figure 32 Cadmium content in biofilm of the Wienfluss

Schwechat River:

In the Schwechat River, the cadmium values varied between 0.07 and 0.49 µg/g (d.w.). Figure 33 is representing the mean values.

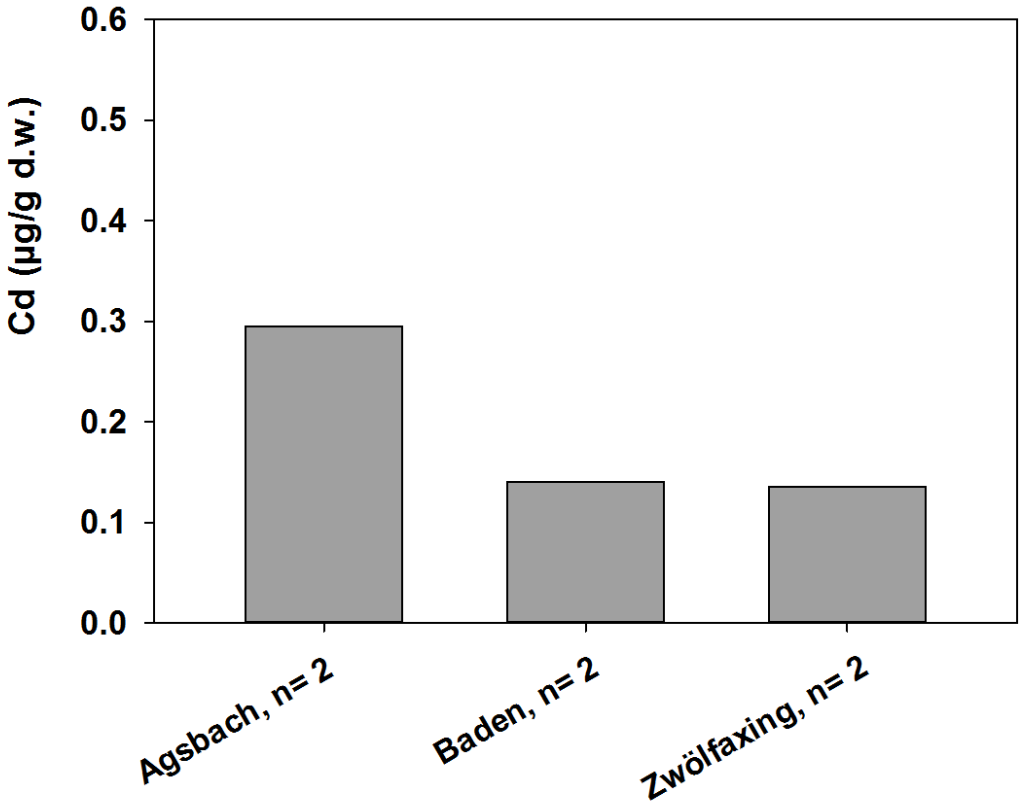

Figure 33 Cadmium content in biofilm of the Schwechat River

3.4.4. Nickel content

For the determination of nickel, all biofilm samples had to be diluted to 1:10. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the nickel values varied between 3 and 45 µg/g (d.w.). Figure 34 is showing the mean values + the 95 % confidence intervals.

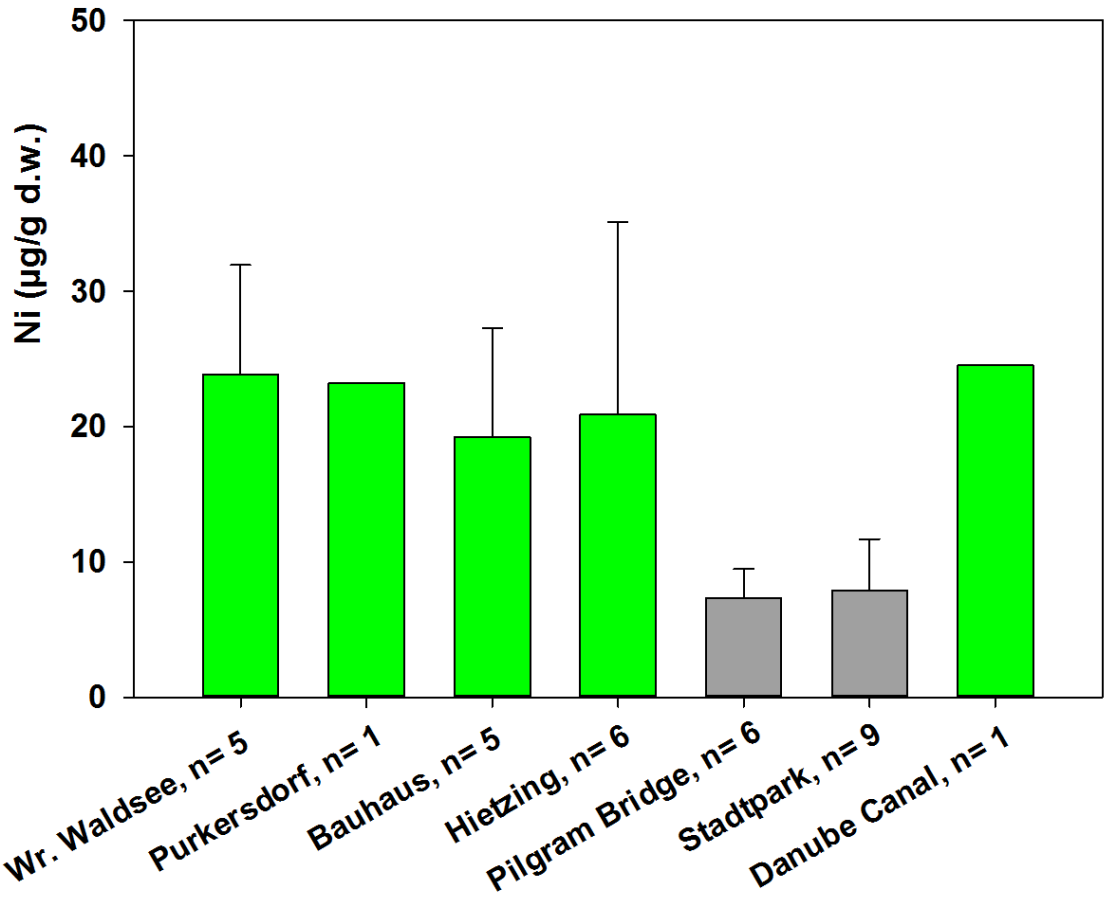

Figure 34 Nickel content in biofilm of the Wienfluss

Schwechat River:

In the Schwechat River, the nickel values varied between 6 and 42 µg/g (d.w.). Figure 35 is representing the mean values.

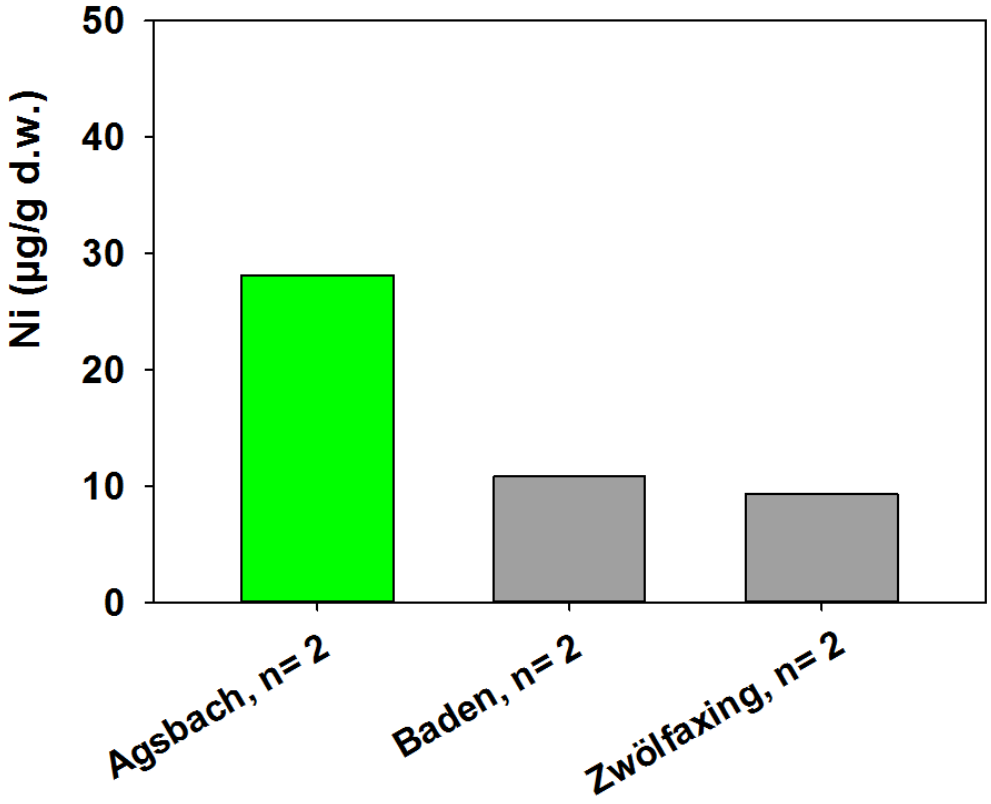

Figure 35 Nickel content in biofilm of the Schwechat River

3.4.5. Chromium content

For the determination of chromium, all biofilm samples had to be diluted to 1:100. The dilutions were made with about 2 % nitric acid.

Wienfluss:

In the Wienfluss, the chromium values varied between 5 and 126 µg/g (d.w.). Figure 36 is showing the mean values + the 95 % confidence intervals.

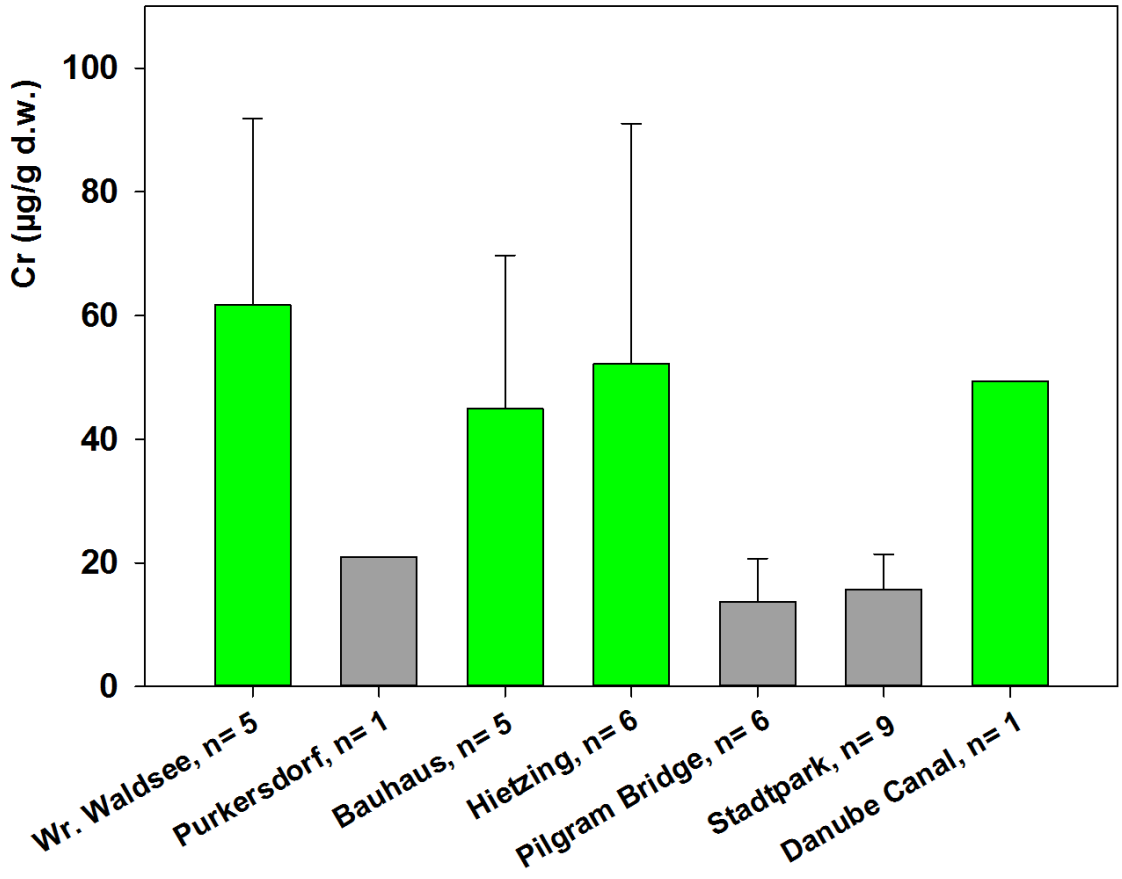

Figure 36 Chromium content in biofilm of the Wienfluss

Schwechat River:

In the Schwechat River, the chromium values varied between 10 and 99 µg/g (d.w.). Figure 37 is representing the mean values.

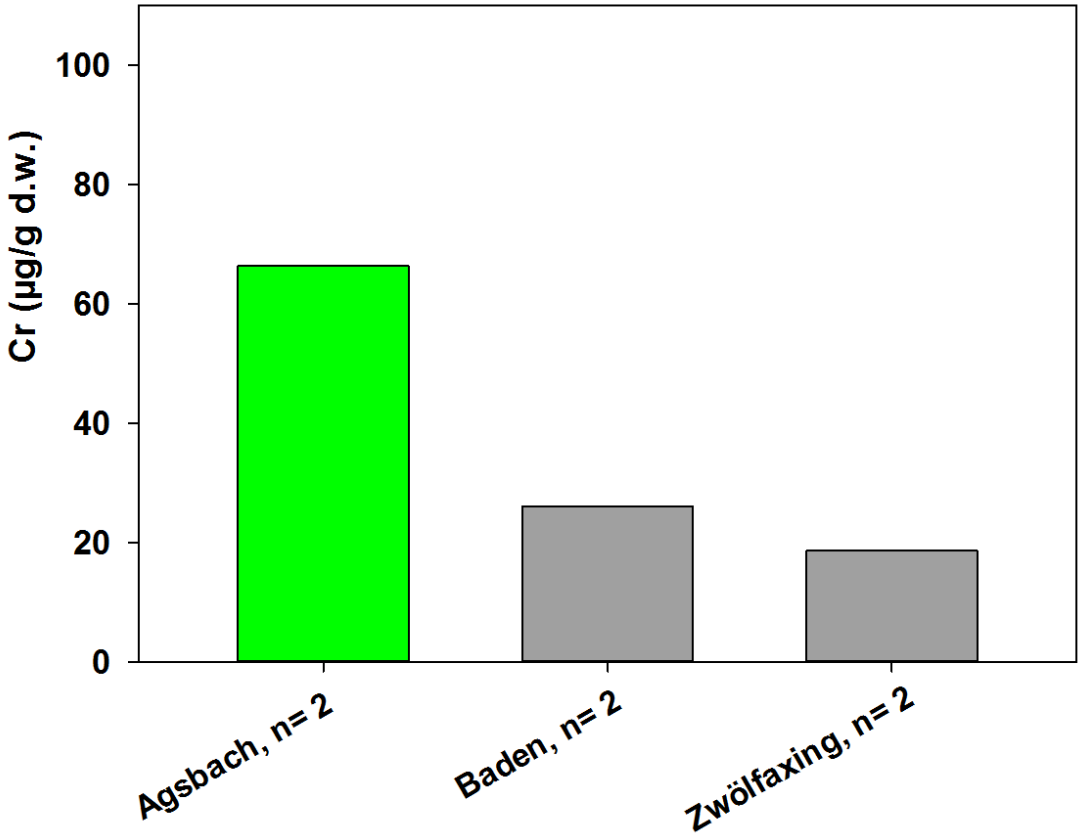

Figure 37 Chromium content in biofilm of the Schwechat River

3.5. Moss

3.5.1. Lead content

For the determination of lead, all moss samples had to be diluted within 0 to 1:10. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the lead values varied between 5 and 70 µg/g (d.w.). Figure 38 is showing the mean values + the 95 % confidence intervals.

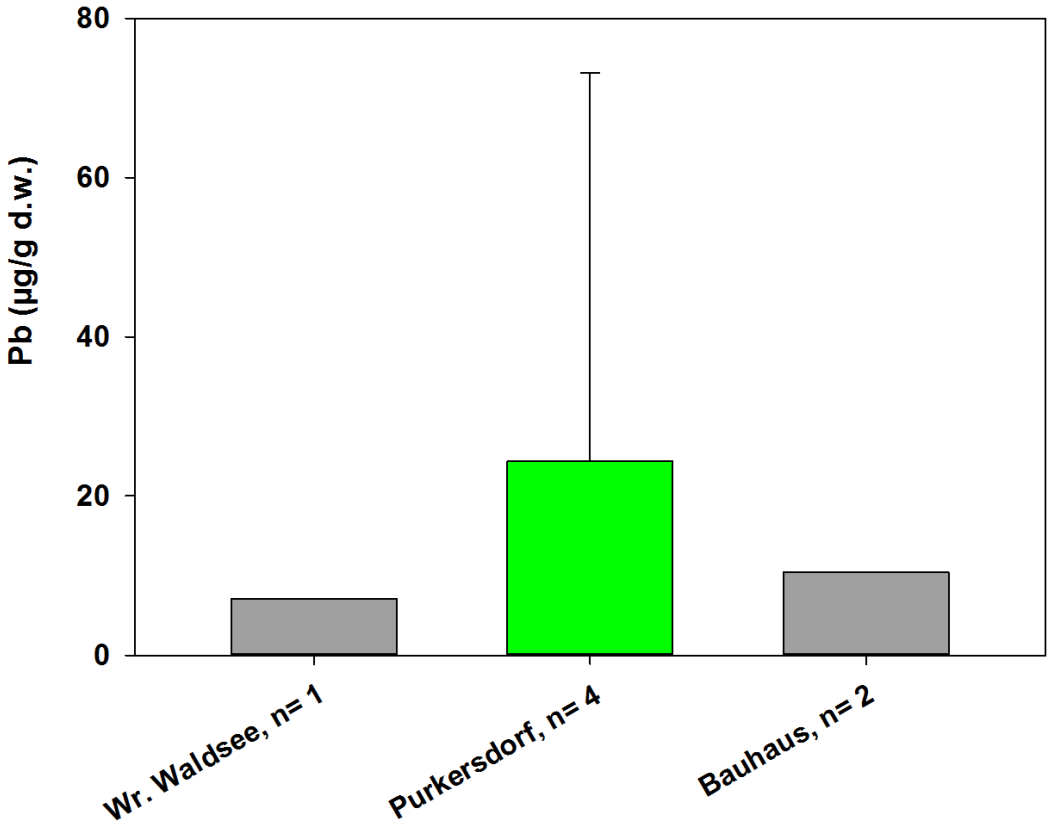

Figure 38 Lead content in moss of the Wienfluss

Schwechat River:

In the Schwechat River, the lead values varied between 3 and 14 µg/g (d.w.). Figure 39 is representing the mean values + the 95 % confidence intervals.

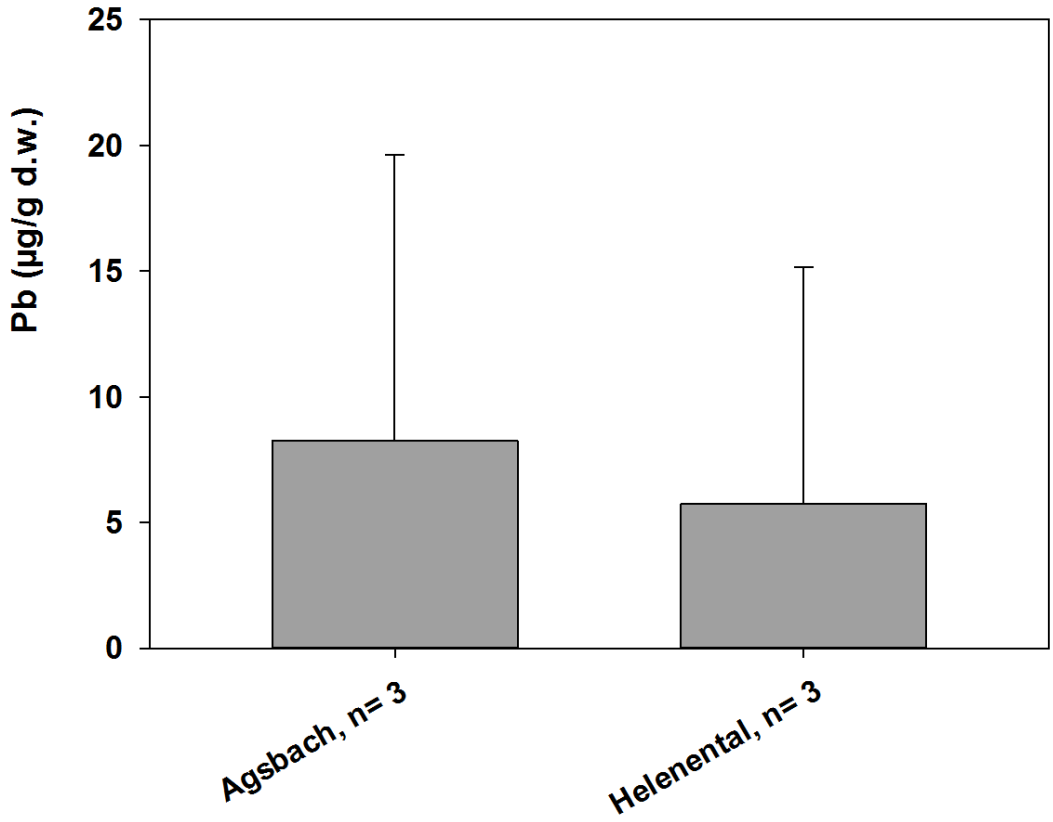

Figure 39 Lead content in moss of the Schwechat River

3.5.2. Copper content

For the determination of copper, all moss samples had to be diluted within 1:10 to 1:100. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the copper values varied between 14 and 64 µg/g (d.w.). Figure 40 is showing the mean values + the 95 % confidence intervals.

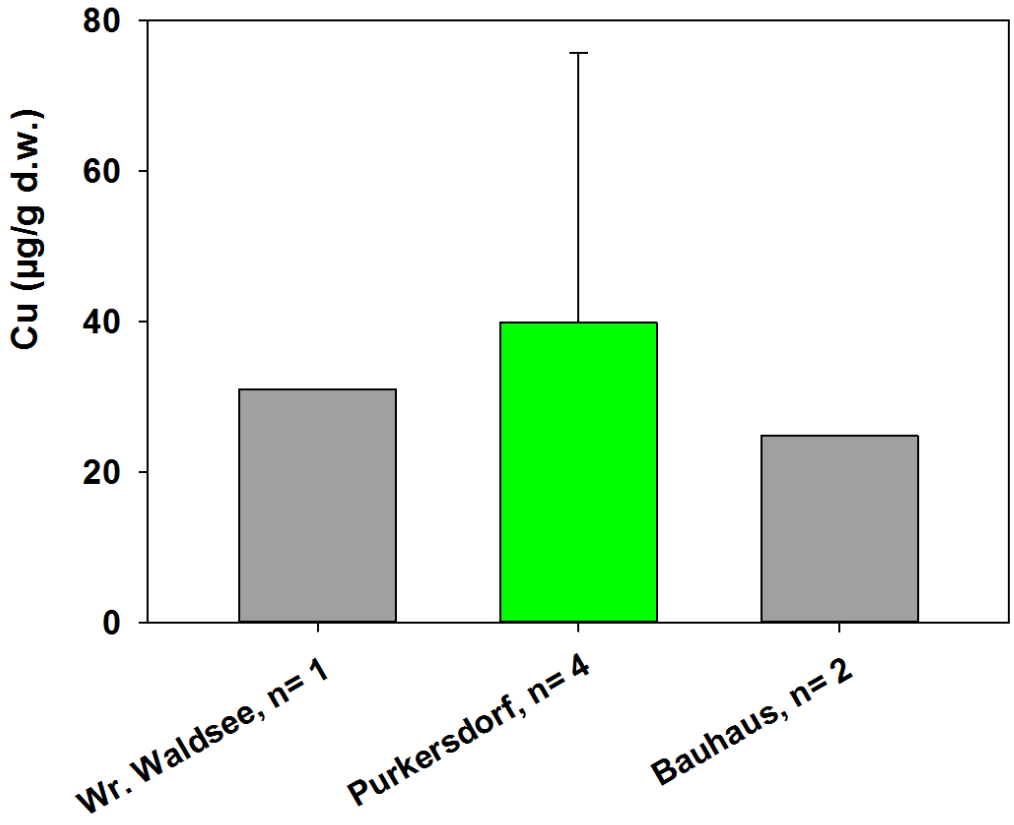

Figure 40 Copper content in moss of the Wienfluss

Schwechat River:

In the Schwechat River, the copper values varied between 9 and 19 µg/g (d.w.). Figure 41 is representing the mean values + the 95 % confidence intervals.

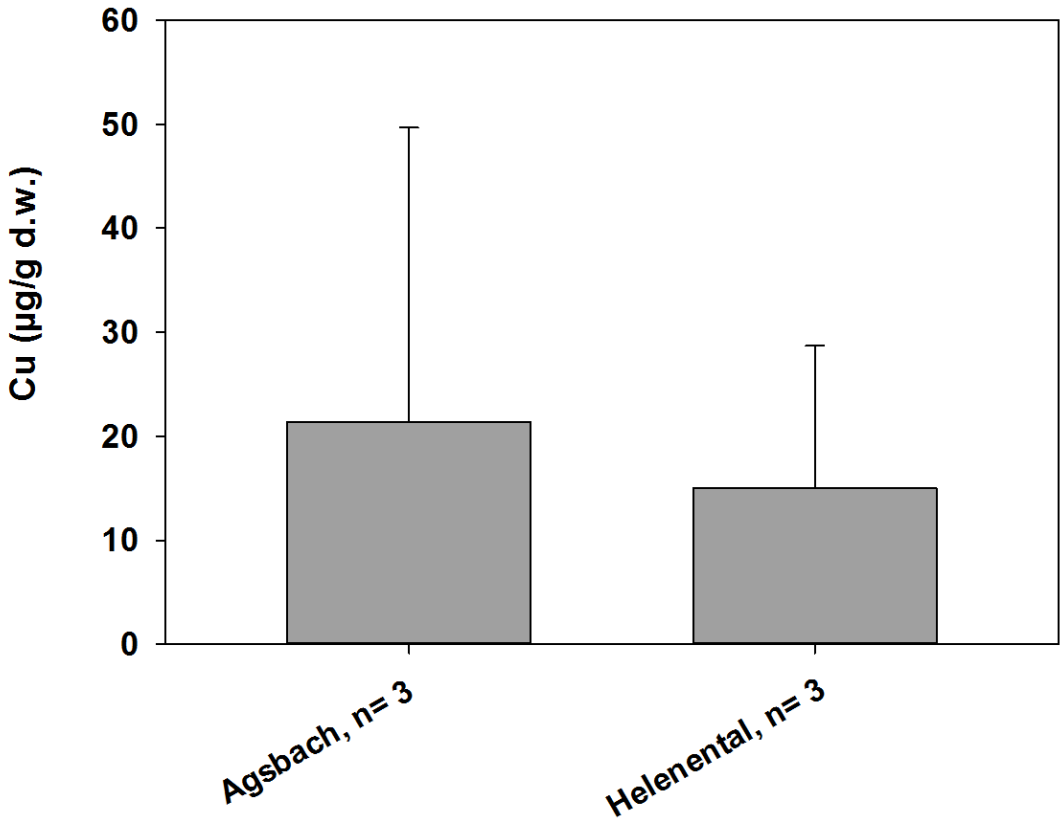

Figure 41 Copper content in moss of the Schwechat River

3.5.3. Cadmium content

For the determination of cadmium, all moss samples had to be diluted to 1:10. The dilutions were made with about 2 % nitric acid.

Wienfluss:

In the Wienfluss, the cadmium values varied between 0.08 and 0.41 µg/g (d.w.). Figure 42 is showing the mean values + the 95 % confidence intervals.

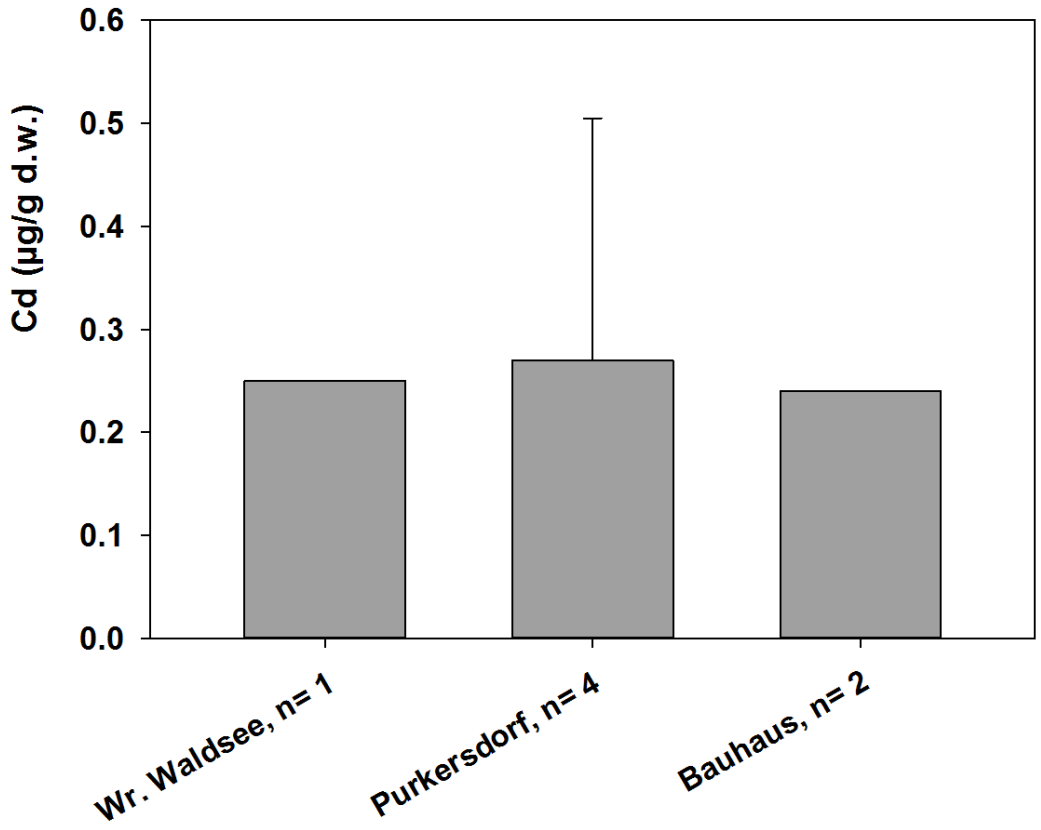

Figure 42 Cadmium content in moss of the Wienfluss

Schwechat River:

In the Schwechat River, the cadmium values varied between 0.07 and 0.75 µg/g (d.w.). Figure 43 is representing the mean values + the 95 % confidence intervals.

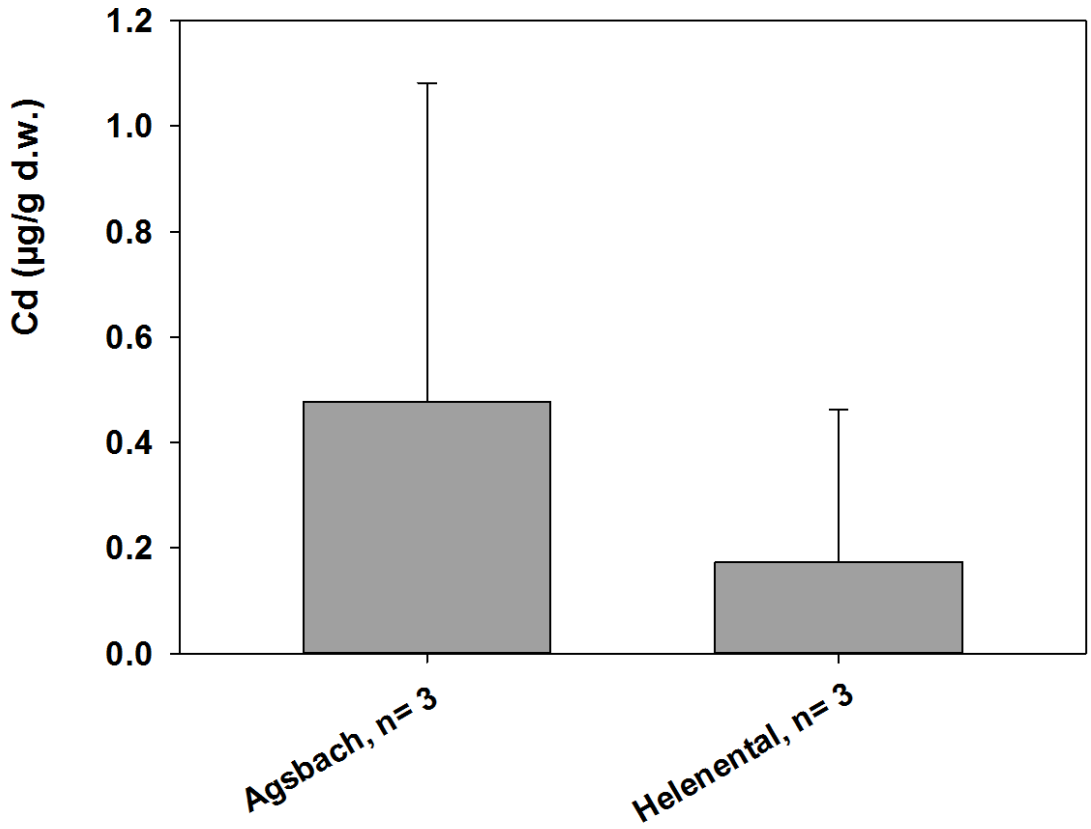

Figure 43 Cadmium content in moss of the Schwechat River

3.5.4. Nickel content

For the determination of nickel, all moss samples had to be diluted to 1:10. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the nickel values varied between 4 and 18 µg/g (d.w.). Figure 44 is showing the mean values + the 95 % confidence intervals.

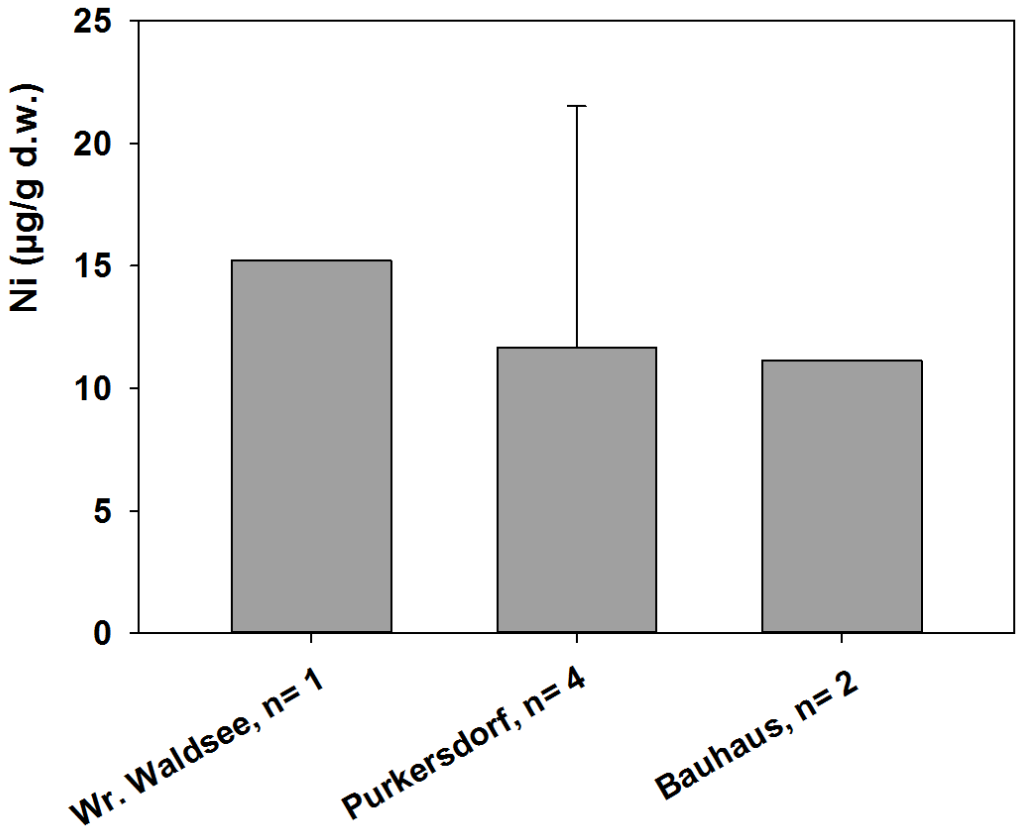

Figure 44 Nickel content in moss of the Wienfluss

Schwechat River:

In the Schwechat River, the nickel values varied between 6 and 28 µg/g (d.w.). Figure 45 is representing the mean values + the 95 % confidence intervals.

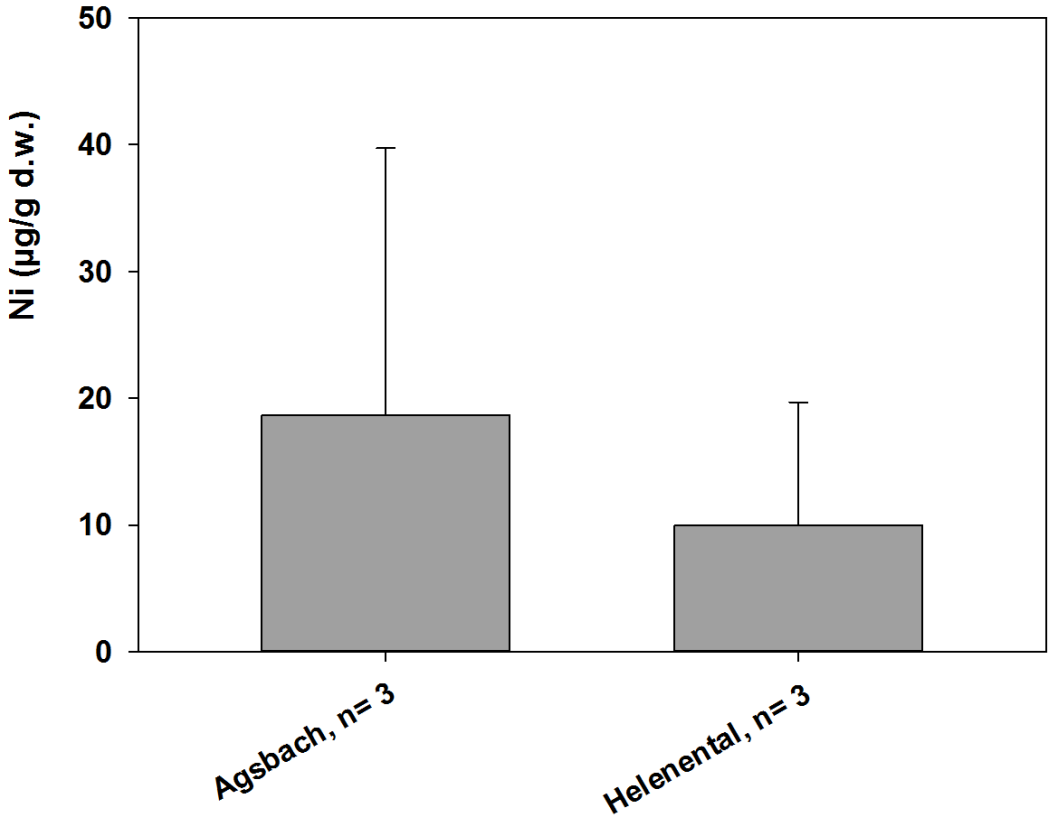

Figure 45 Nickel content in moss of the Schwechat River

3.5.5. Chromium content

For the determination of chromium, all moss samples had to be diluted to 1:100. The dilutions were made with ~ 2 % nitric acid.

Wienfluss:

In the Wienfluss, the chromium values varied between 10 and 32 µg/g (d.w.). Figure 46 is showing the mean values + the 95 % confidence intervals.

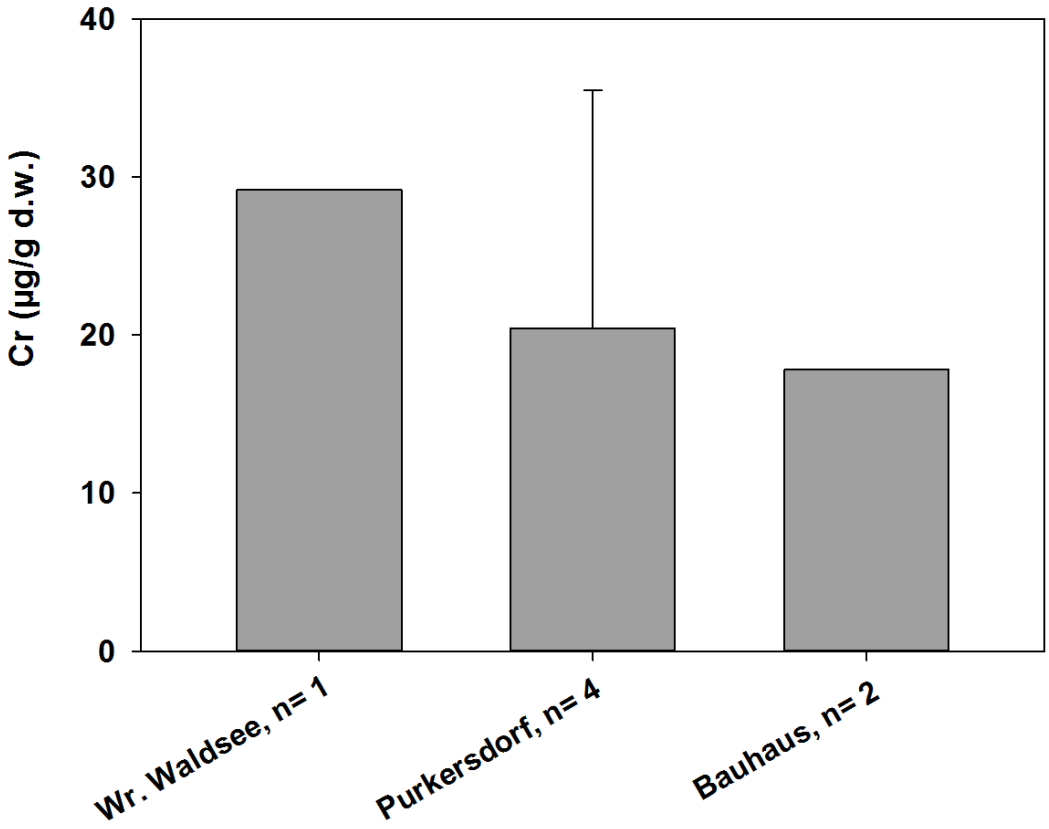

Figure 46 Chromium content in moss of the Wienfluss

Schwechat River:

In the Schwechat River, the chromium values varied between 12 and 46 µg/g (d.w.). Figure 47 is representing the mean values + the 95 % confidence intervals.

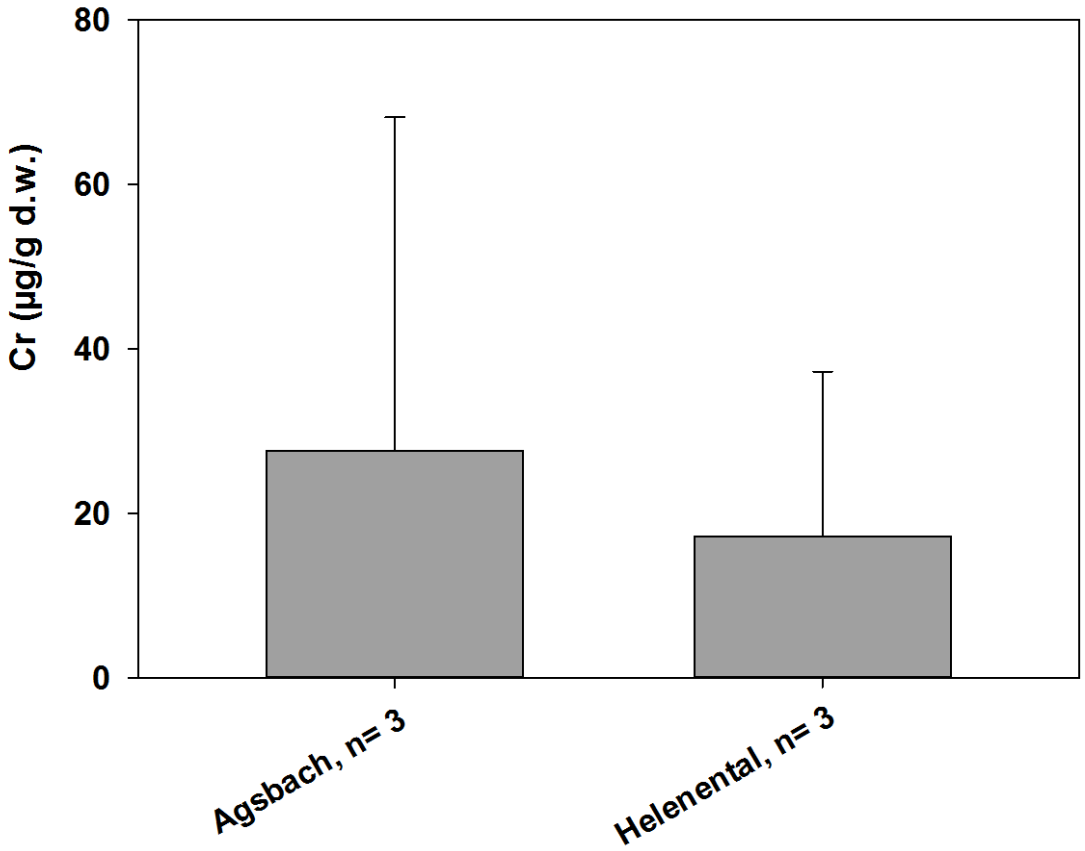

Figure 47 Chromium content in moss of the Schwechat River

3.6. Fish

3.6.1. Lead content

Wienfluss:

From the eight *L. cephalus* samples (liver tissue), lead was only found in 4 samples. In addition, the lead values from the three *P. fluviatilis* (liver tissue) were below the LOD. Moreover, there was no measurable lead content in the muscle tissue of both fish species. The lead values in the liver tissue varied between 0.005 and 0.047 µg/g wet weight (w.w.). Figure 48 is representing the mean values + the 95 % confidence intervals.

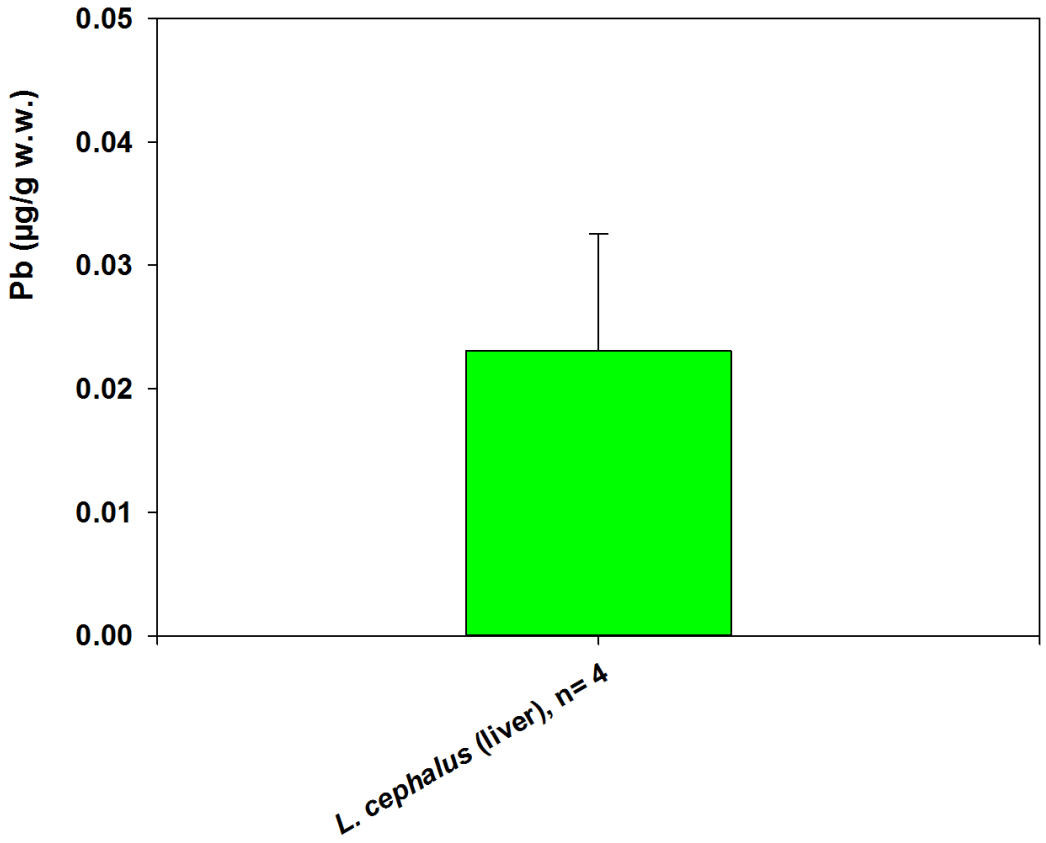

Figure 48 Lead content in liver tissue of the Wienfluss

Schwechat River:

From the eight *G. gobio* samples (muscle tissue), lead was found in seven samples. The other sample had a lead value below the LOD. In addition, from eleven *L. cephalus* samples (muscle tissue), lead was found in five samples. The other samples had lead amounts found below the LOD. The lead values in the muscle tissue varied between 0.001 and 0.044 µg/g (w.w.). Figure 49 is representing the mean values + the 95 % confidence intervals.

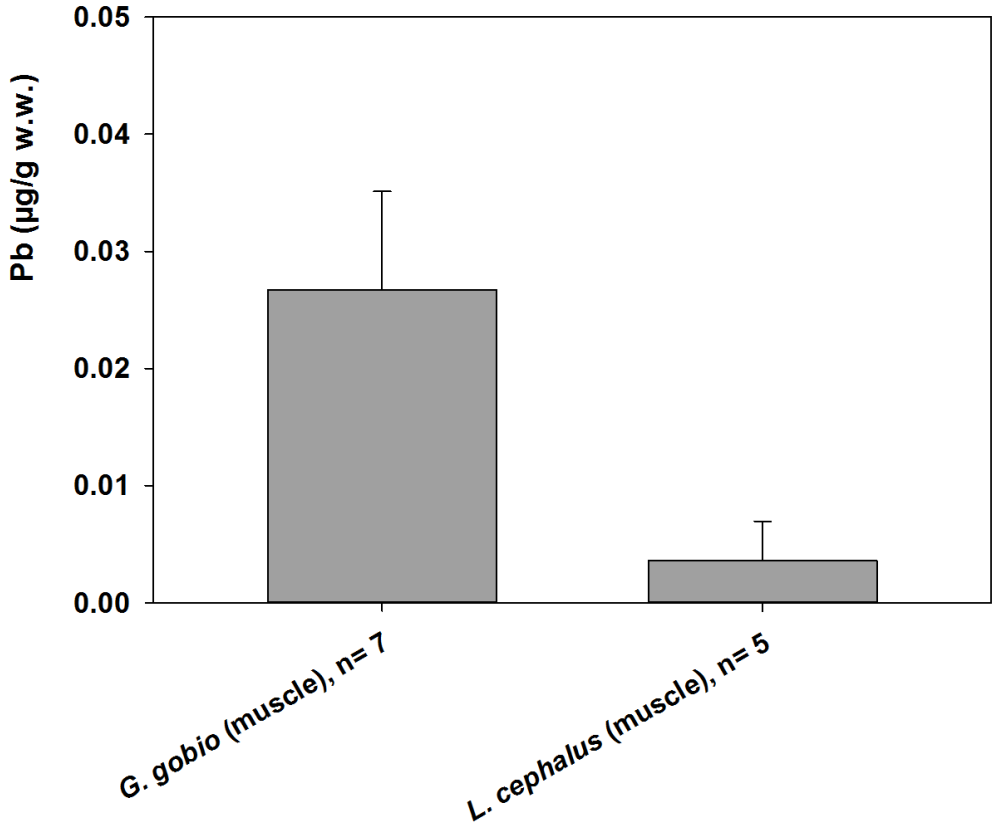

Figure 49 Lead content in muscle tissue of the Schwechat River

3.6.2. Copper content

Wienfluss:

Copper was measured in the liver and muscle tissue from *L. cephalus* and *P. fluviatilis*. All liver tissue samples had to be diluted within 1:10 to 1:100. The copper values in the muscle tissue of this two fish species varied between 0.10 and 0.35 µg/g (w.w.). In addition, the copper values in the liver tissue of this two species varied between 2.1 and 24.2 µg/g (w.w.). Figure 50 is representing the mean values + the 95 % confidence intervals.

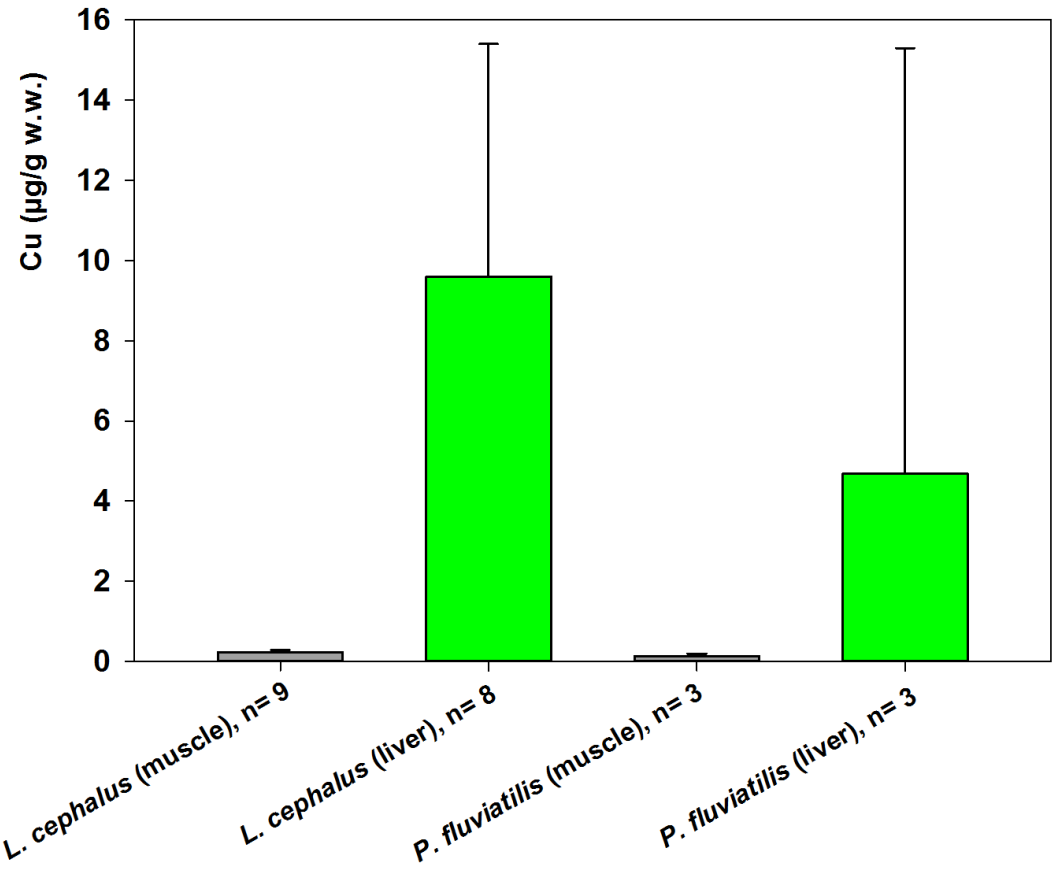

Figure 50 Copper content in muscle and liver tissue of the Wienfluss

Schwechat River:

In the Schwechat River, the copper values in the muscle tissue of this two fish species varied between 0.14 and 0.58 µg/g (w.w.). Figure 51 is representing the mean values + the 95 % confidence intervals.

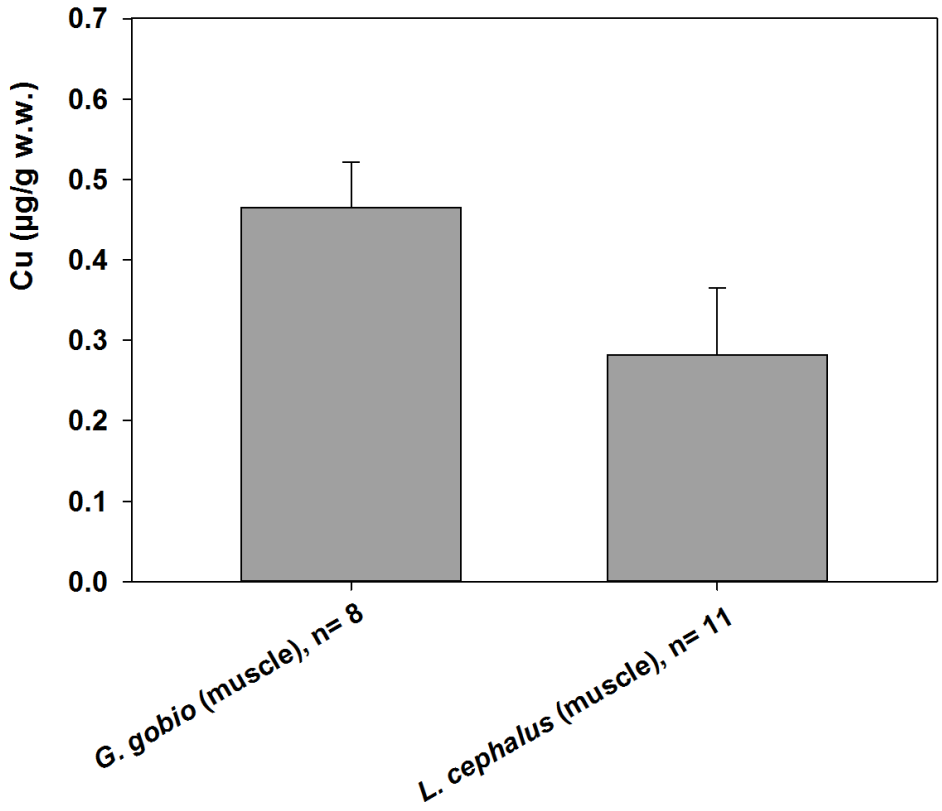

Figure 51 Copper content in muscle tissue of the Schwechat River

3.6.3. Cadmium content

Wienfluss:

Cadmium was measured in the liver and muscle tissue from *L. cephalus* and *P. fluviatilis*. The cadmium values in the muscle tissue of this two fish species varied between 0.001 and 0.004 µg/g (w.w.). In addition, the cadmium values in the liver tissue of this two species varied between 0.005 and 0.014 µg/g (w.w.). Figure 52 is representing the mean values + the 95 % confidence intervals.

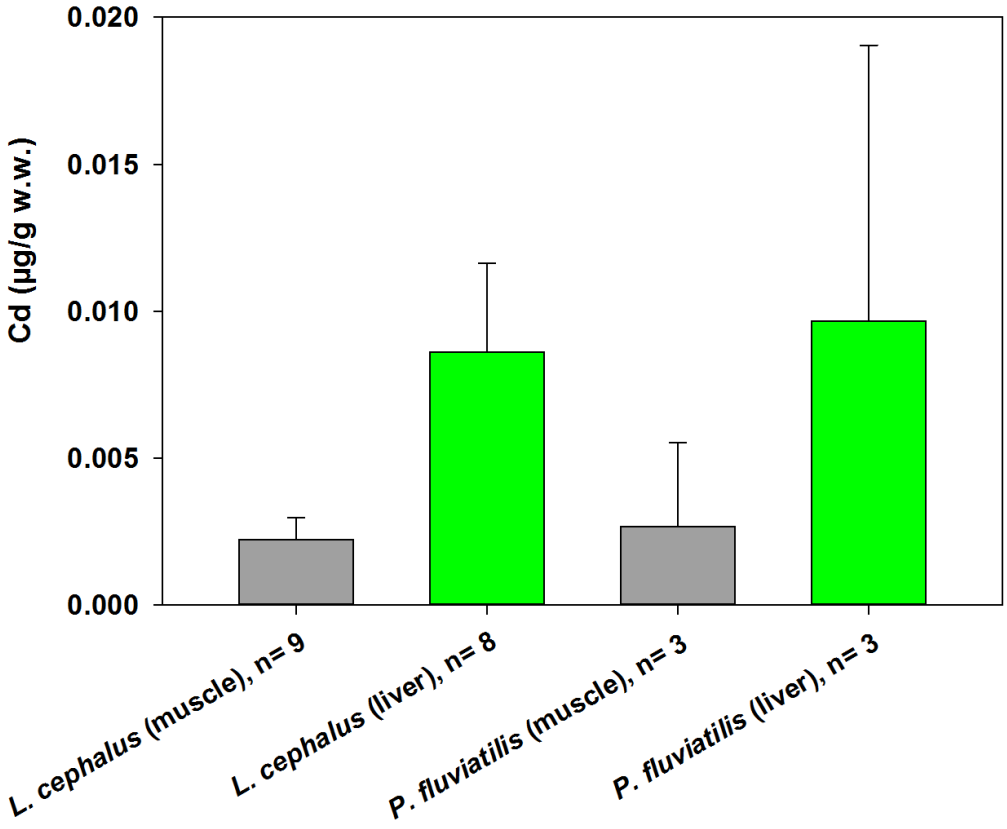

Figure 52 Cadmium content in muscle and liver tissue of the Wienfluss

Schwechat River:

In the Schwechat River, the cadmium values in the muscle tissue of this two fish species varied between 0.0004 and 0.004 µg/g (w.w.). Figure 53 is representing the mean values + the 95 % confidence intervals.

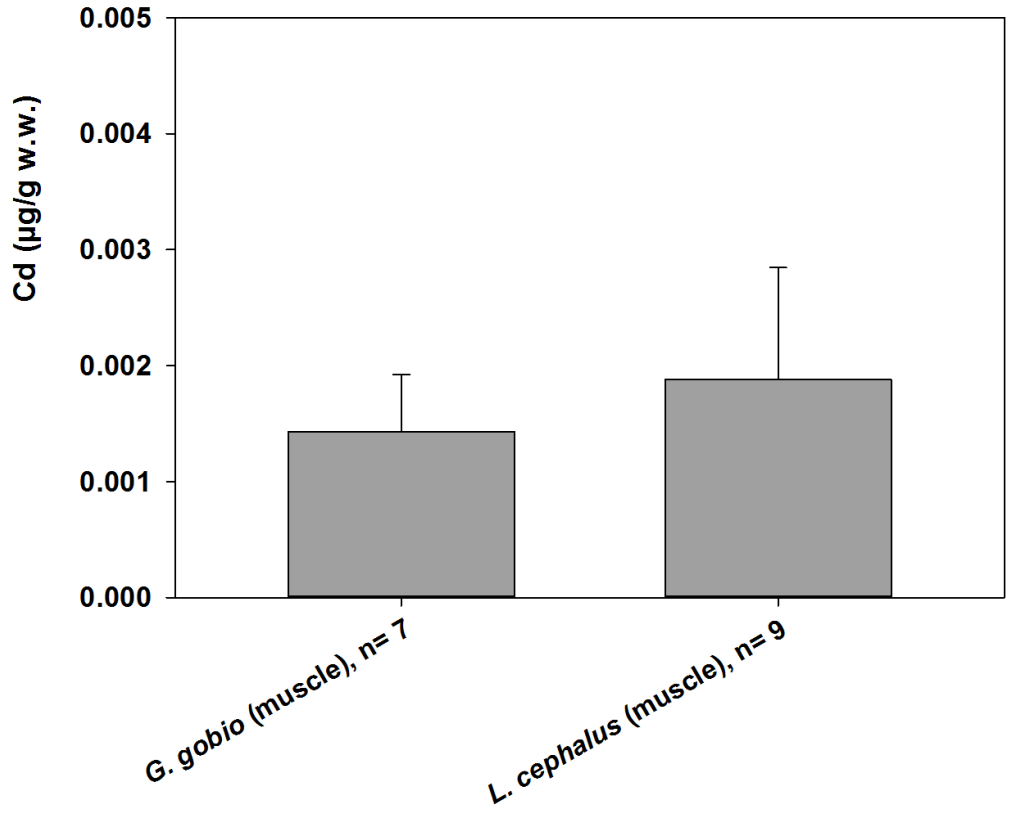

Figure 53 Cadmium content in muscle tissue of the Schwechat River

3.6.4. Nickel content

Wienfluss:

Nickel was measured in the liver and muscle tissue from *L. cephalus* and *P. fluviatilis*. From the nine *L. cephalus* samples (muscle tissue) nickel was only found in two samples. From the three *P. fluviatilis* (muscle tissue) values, one was higher than the LOD.
The nickel values in the muscle tissue of this two fish species varied between 0.002 and 0.009 µg/g (w.w.). In addition, the nickel values in the liver tissue of this two species varied between 0.015 and 0.049 µg/g (w.w.). Figure 54 is representing the mean values + the 95 % confidence intervals.

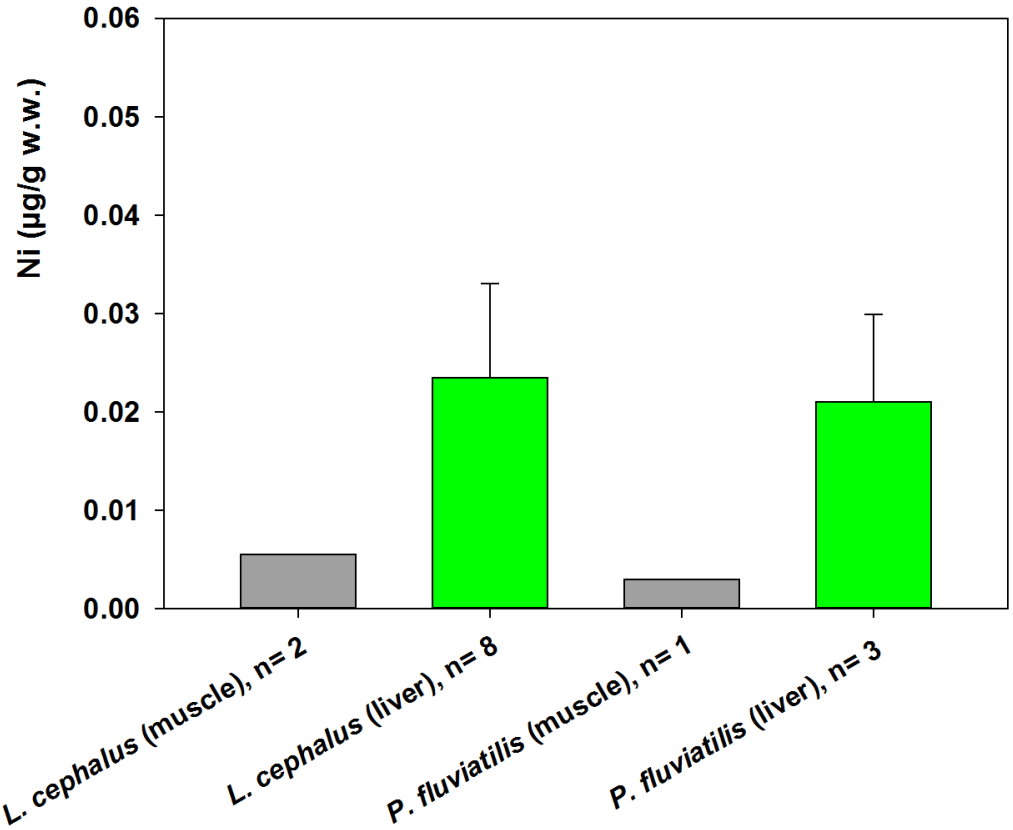

Figure 54 Nickel content in muscle and liver tissue of the Wienfluss

Schwechat River:

In the Schwechat River, the nickel values in the muscle tissue of this two fish species varied between 0.005 and 0.219 µg/g (w.w.). Figure 55 is representing the mean values + the 95 % confidence intervals.

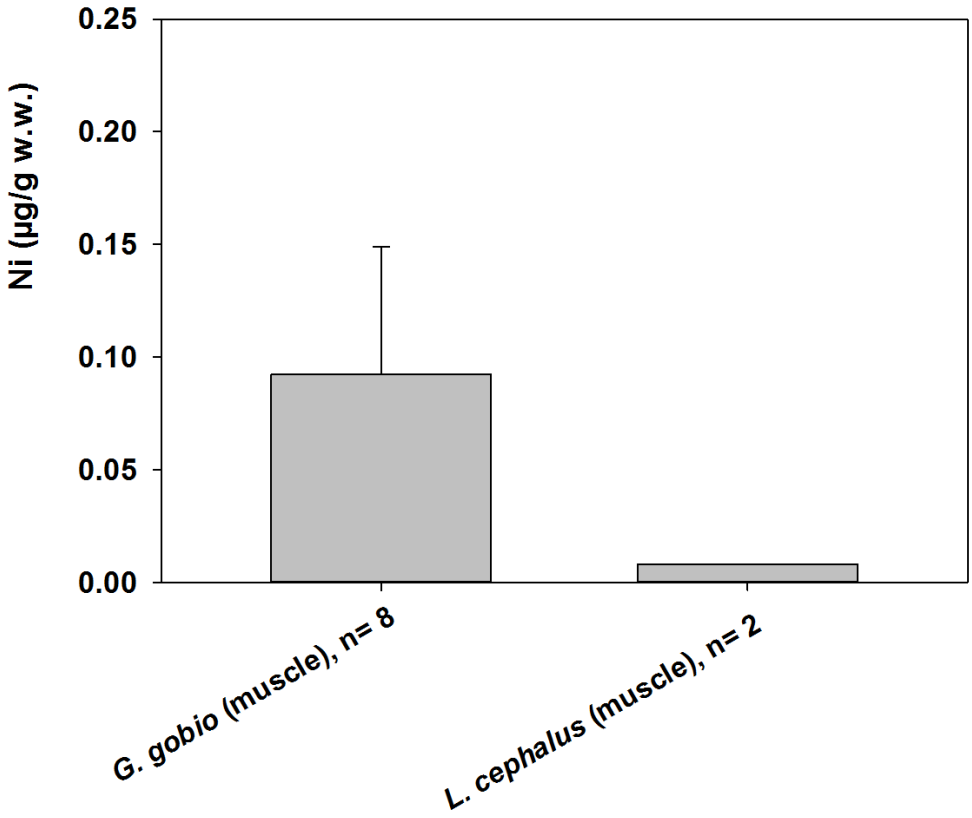

Figure 55 Nickel content in muscle tissue of the Schwechat River

3.6.5. Chromium content

Wienfluss:

Chromium was measured in the liver and muscle tissue from *L. cephalus* and *P. fluviatilis*. All liver tissue samples had to be diluted to 1:10. The chromium values in the muscle tissue of this two fish species varied between 0.01 and 0.06 µg/g (w.w.). In addition, the chromium values in the liver tissue of this two species varied between 0.25 and 0.51 µg/g (w.w.). Figure 56 is representing the mean values + the 95 % confidence intervals.

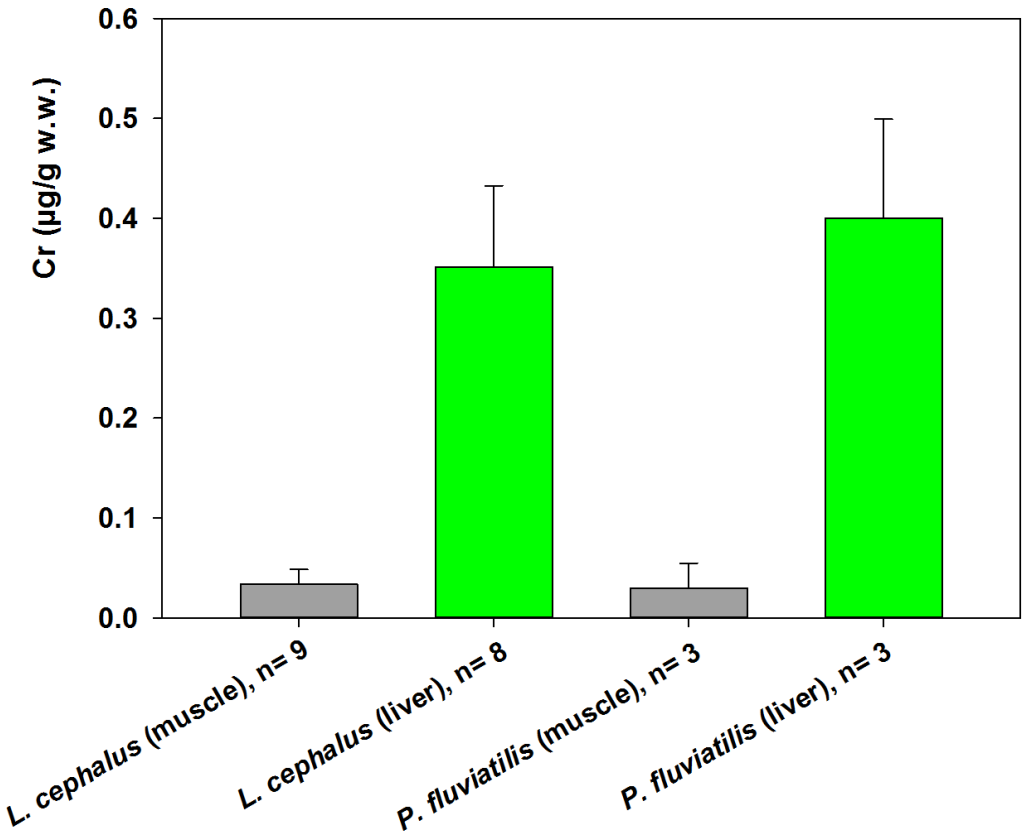

Figure 56 Chromium content in muscle and liver tissue of the Wienfluss

Schwechat River:

All muscle tissue samples had to be diluted to 1:10. In the Schwechat River, the chromium values in the muscle tissue of this two fish species varied between 0.01 and 0.18 µg/g (w.w.). Figure 57 is representing the mean values + the 95 % confidence intervals.

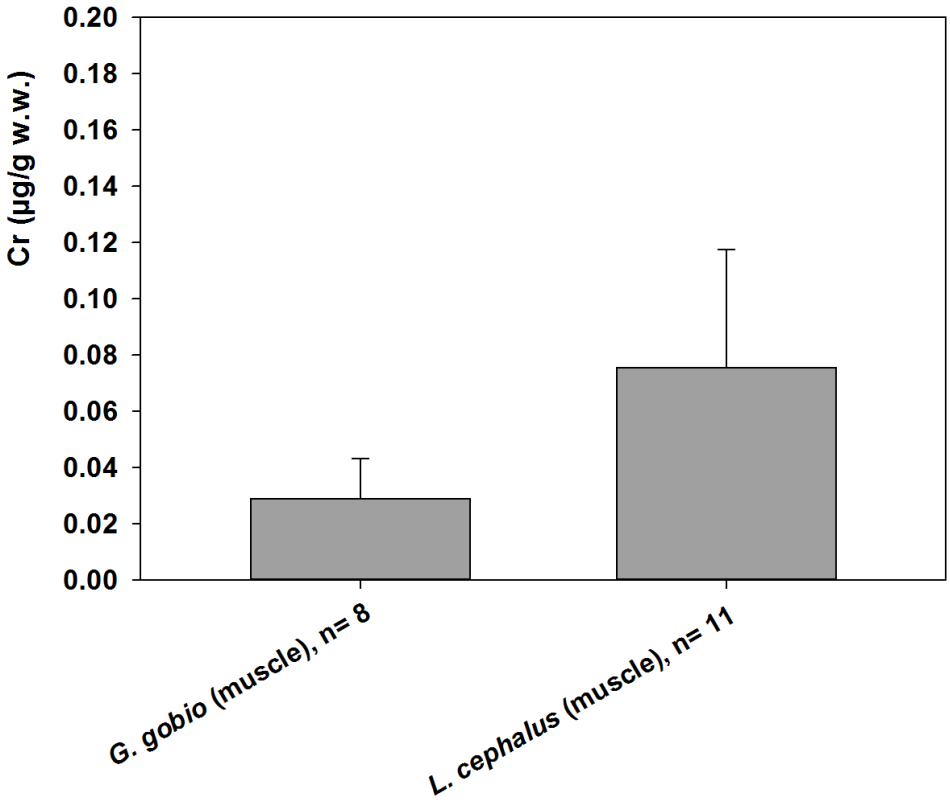

Figure 57 Chromium content in muscle tissue of the Schwechat River

3.7. Fish parasite (*Pomphorhynchus laevis*)

3.7.1. Heavy metal content

Four *P. laevis* samples were analyzed for various HM. The original samples had to be diluted to 1:10 for lead, to 1:100 in the case of copper, and to 1:10 for chromium. The lead values varied between 4.9 and 26 µg/g (w.w.), the copper values varied between 17 and 44.8 µg/g (w.w.), the nickel values varied between 0.007 and 1.2 µg/g (w.w.), and the chromium values varied between 0.1 and 3.8 µg/g (w.w.), as illustrated in figure 58.

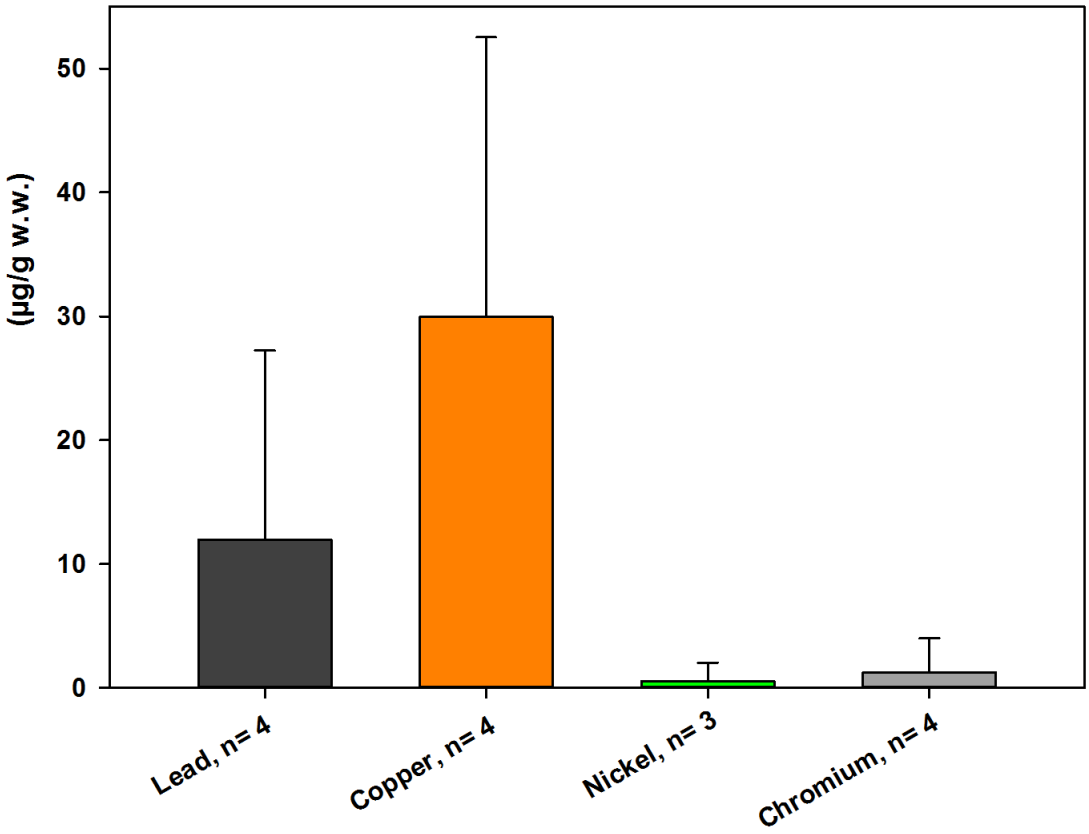

Figure 58 HM content in *P. laevis* of the Schwechat River

The ratios between the metal concentration in parasites and fish muscle tissue are shown in table 12.

Table 12 Concentration factor of metals in *P.laevis* calculated in muscle tissue of *L. cephalus*, b.d. = at least one value was below the detection limit.

Element	Mean	SD	Min	Max
Copper				
$C_{P.\ laevis}/\ C_{muscle}$	81.2	99.1	43.7	213.1
Lead				
$C_{P.\ laevis}/\ C_{muscle}$	b.d.	–	–	–
Nickel				
$C_{P.\ laevis}/\ C_{muscle}$	b.d.	–	–	–
Chromium				
$C_{P.\ laevis}/\ C_{muscle}$	21.4	74.9	0.8	125.3

4. Discussion

4.1. LOD

The evaluation of the instrumental LOD is basically the first step to figure out the capacity of a brand new instrument. For constructive results on various HM, the most important step is the cleaning and precise work with the item. The sensitivity can be particularly increased or decreased depending on the wavelength [63]. Carnrick gives a characteristic mass of 10 pg for lead in the case of a transversal heated GFAAS with background correlation and without using a modifier solution. In addition, Carnrick gives a distinguishing mass of 8 pg for copper in the longitudinal headed working GFAAS with background correlation. Many authors give a LOD for cadmium within the range of 80 ng/L. Slavin *et al*. give a characteristic mass of 20 pg in the case of nickel within a sensitive wavelength. Slavin *et al*. also give a characteristic mass of 7 pg in the case of chromium by using a modifier.

4.2. Sediment

The evaluated sediment data from the Wienfluss shows an interesting HM trend. The highest HM content, such as that of copper and lead, was found at the Stadtpark-site. The lead values were extremely high. The mean lead content in sediment in the Stadtpark was classified as heavily contaminated according to Müller [10]. Scientific investigations form Kralik and Sager [66] proposed that the accumulation of lead in sediment comes from small and tranquil flows. Indeed, sampling locations close to the influent stream have shown particularly high lead values. Furthermore, the influent stream in the Stadtpark was the only supply for the high lead and copper concentrations. See figure 59 for comparison to the other locations in which samples were taken. In fact, the lead accumulation in sediment along the Wienfluss varied from one location to another. This result is confirmed by the Austrian annual report of water quality. Such excess of lead could be the result of industrial activity and/or the population density. Due to the fact that there are persons involved in several activities or even homeless people living in the Stadtpark area, pollution might be

influenced through distinct anthropogenic factors. The cadmium, nickel and chromium concentrations in all compartments showed non-polluted values and also are well comparable to the results from the Austrian annual report of water quality.

Figure 59 Wienfluss sample location at Stadtpark (6)

The evaluated sediment data from the Schwechat River showed that all HM concentrations increased along the Schwechat River. The HM concentration studies conducted by Zheng *et al*. (2007) [67] in different locations along surface sediments of freshwater rivers in Huludao City (Northeast China) are suitable to compare the results obtained in the Schwechat River. This work also included lead copper and cadmium measurements along the rivers that eventually reach urban areas in which the HM pollution was higher due to industrialization and anthropogenic influences. The Lianishan River showed no direct pollution sources within the first two sampling locations when comparing the HM content in sediment. The mean lead, copper and cadmium values were 62 µg/g d.w., 47 µg/g d.w. and 1.6 µg/g d.w., respectively. In addition, the HM content was much higher in lower reaches of the Cishan River, where a zinc plant is located. The mean lead, copper and cadmium values there were 1137 µg/g d.w., 514 µg/g d.w. and 645 µg/g d.w., respectively. Indeed, this reflects the result of anthropogenic pollution in aquatic sediment. This reference is actually confirming

the results from the Wienfluss and Schwechat rivers. The samples taken close to where the Schwechat River originates (Agsbach) reflected a lower HM content in comparison to the other sample location (Zwölfaxing), on which the river kept on flowing. This HM concentration increase may be the result of atmospheric deposition. The results along the Wienfluss shows a scattered pattern of anthropogenic pollution e.g. lead and copper content in the Stadtpark.

4.3. Biofilm

The obtained biofilm data from the Wienfluss showed that the lead accumulation in the Stadtpark was the highest, in contrast to the other compartments. The lead content at Hietzing and Bauhaus was slightly elevated. The copper content in Hietzing was much higher than that in the sediment. The cadmium, nickel and chromium values from all compartments were similar.

The results in the Schwechat River showed that in Agsbach the HM content was higher than in the other locations.

Several studies have shown that biofilms accumulate metals [68–70] at concentrations often greater than those in sediments [71, 72]. A HM accumulation study of natural living biofilms was conducted by Mages *et al*. (2002) [73] in different locations along the Trisza River (Hungary). The mean lead, copper, nickel and chromium values from the sampling in the year 2000 were 10.1 µg/g d.w., 118 µg/g d.w., 17.5 µg/g d.w. and 10.3 µg/g d.w., respectively. These results are partially similar to the HM content in biofilm obtained from the Schwechat River and the Wienfluss. Indeed, the lead data from the Schwechat River, as well as the nickel and chromium data obtained from both; the Schwechat River and the Wienfluss are similar to those of Mages *et al*.. The very high HM concentration of lead and copper in the Stadtpark actually reflects the urban influence in the ecosystem.

4.4. Moss

Given that moss accumulates HM throughout the years without being affected by this accumulation, they are especially suitable for bioaccumulation of atmospheric deposition [74].

The collected data from the Wienfluss pointed out in particular that the lead and copper values were greater there than in the others. Unfortunately, there were just few sample locations where moss was taken. The results in the Schwechat River are reflecting the same as the biofilm results. The moss in Agsbach showed higher HM accumulation than in the other compartments.

A HM accumulation study of mosses including *F. antipyretica* was conducted by Gapeeva *et al*. (2008) [74] in small and medium rivers of Vologda and Kostroma oblasts (Russia). HM such as lead, copper, cadmium and chromium were investigated. The lead, copper, cadmium and chromium values reached from 0.2 – 13.8 µg/g d.w., 0.5 – 22 µg/g d.w., 0.03 – 1.05 µg/g d.w. and 0.4 – 6.8 µg/g d.w., respectively.

These results are partially similar to the HM content in moss obtained from the Schwechat River and the Wienfluss.

4.5. Fish

The results obtained from the investigated fish tissues collected in the Wienfluss demonstrated that from all the analyzed HM, a higher HM content was present in the liver than in muscle. Muscle tissues were only analyzed for HM from the samples obtained in the Schwechat River. *G. gobio* represented a much higher lead concentration than *L. cephalus*, which was even higher than that in the liver tissue of *L. cephalus*. This is probably because *G. gobio* is living in the ground of flowing waters, and *L. cephalus* lives on surface waters when they are of younger age [75]. In general, *G. gobio* showed higher HM concentrations than the *L. cephalus*, except for chromium.

A HM accumulation study of the *P. fluviatilis* was conducted by Tkatcheva *et al*. (2000) [76] in the downstream from the lake Kostomuksha (Russia) close to an iron pellet production, where the concentrations of different HM such as copper, cadmium, nickel and chromium in fish liver and muscle were analyzed. The HM values from the Poppalijavi lake, which is the closest river to the plant, were for copper in liver and muscle 9.66 µg/g d.w. and 0.87 µg/g d.w., respectively; for cadmium in liver and muscle 1.76 µg/g d.w. and 0.01 µg/g d.w., respectively; for nickel in liver and muscle 0.09 µg/g d.w. and 0.04 µg/g d.w., respectively; and for chromium 0.08 µg/g d.w. and 0.05 µg/g d.w., respectively. By comparing these data with the Wienfluss data in table 13 an interesting trend is given. The concentration of essential HM such as copper and chromium, especially in the liver tissue, is much higher

than that from the fish in the Poppalijavi River. In addition, the cadmium concentration of *P. fluviatilis* in the lake Poppalijavi is 35 times higher than that in the Wienfluss. The nickel values are similar.

Table 13 Heavy metal concentrations (mean of µg/g d.w.) in *P. fluviatilis* liver and muscle tissue of the Wienfluss.

Metal	Liver	Muscle
Cu	22.65	0.63
Cd	0.05	0.01
Ni	0.10	0.01
Cr	1.93	0.14
n	3	3

Another HM accumulation study of the *G. gobio* was conducted by Bervoets *et al*. (2003) [77] in metal polluted lowland rivers in Flanders (Belgium), where the concentrations of different HM such as lead, copper, cadmium, nickel and chromium in fish liver and muscle were analyzed.

Table 14 Heavy metal concentrations (mean of µg/g d.w.) in *G.gobio* liver and muscle tissue of the Schwechat River (S.R.) and one of the Flanders Rivers (F.R.)

Metal	Muscle (S.R.)	Muscle (F.R.)
Pb	0.13	0.1
Cu	2.25	0.6
Cd	0.01	0.6
Ni	0.45	0.1
Cr	0.14	0.1
n	8	8–10

By comparing the S.R. and one of the F.R. data in table 14 the essential HM concentration of copper in the S.R. in muscle tissue is higher than the F.R. The chromium data are representing a similar pattern. The cadmium concentration of *the G. gobio* in the Schwechat River is much lower compared to the other one.

A HM accumulation study of the *L. cephalus* was conducted by Casiot *et al*. (2009) [78] where the downstream of the Amous River (France) was monitored in regards to the possible contamination impact by a Pb-Zn mine. The concentrations of different HM such as lead, copper, and cadmium in fish liver and muscle were analyzed.

Table 15 Heavy metal concentrations (mean of µg/g d.w.) in *L. cephalus* liver, muscle tissue of the Wienfluss and muscle tissue of the Schwechat River (S.R.)

Metal	Liver	Muscle	Muscle (S.R.)
Pb	0.08	<LOD	0.01
Cu	46.38	1.14	1.36
Cd	0.04	0.01	0.01
n	8	9	11

The HM values from the downstream of the Amous River were for lead in liver and muscle 0.54 µg/g d.w. and 0.09 µg/g d.w., respectively; for copper in liver and muscle 9.8 µg/g d.w. and 0.38 µg/g d.w., respectively; and for cadmium 0.72 µg/g d.w. and 0.01 µg/g d.w., respectively. Compared with the data from table 15 it can be observed that the lead and cadmium levels in the liver tissue from the *L. cephalus* of the Amous River are much higher that the values obtained from the same fish species in the Wienfluss.

4.6. Parasite

The results pointed out that *P. laevis* accumulates huge amounts of lead. Without a doubt, the *P. laevis* contained a much higher lead amount than their host. For instance, two infected muscle tissue samples from the *L. cephalus* did not quantify lead. Several papers from Sures *et al*. are congruent to these results. This indicates that parasites may serve as a very susceptible and useful bioindicator, especially for lead and other HM in aquatic ecosystems, or for making conclusions about pollution.

5. Summary

For the present masterwork various heavy metal measurements were executed using a PerkinElmer® PinAAcle™ 900Z atomic absorption spectrometer. The first practical part of this thesis was to achieve a reliable calibration and define the instrumental limit of detection (LOD) for the selected elements: lead, copper, cadmium, nickel and chromium. Furthermore, the analysis of certified reference material from the National Research Council Canada (NRCC), including marine sediment (PACS-2), fish protein (DORM-3) and fish liver (DOLT-3) were performed in order to validate the methods used. The measurement of digested samples of sediment, biofilm, moss, fish and fish parasites from the Wienfluss and the Schwechat River, Lower Austria completed the practical work. The results showed an infrequent lead accumulation in riverine sediment, particularly at the Wienfluss Stadtpark area. In addition, it was observed that lead accumulation in the biofilm increased. The moss samples from the Wienfluss and the Schwechat River also indicated a HM accumulation. This demonstrates the unique characteristic of moss and biofilms as bioindicator for HM. The fish results presented a higher HM accumulation in liver than in muscle tissue. The highest HM content of copper in the liver tissues supported the fact that this HM is essential for proper living functions. The extreme high lead accumulation in the fish parasites from the acanthocephalan species *Pomphorhynchus laevis* confirmed that these fish parasites are included within the routes of fish HM detoxification. In contrast to the parasites, the infected fish counted a lead content below the LOD in the muscle tissue. The fish from where the parasite with the highest lead accumulation came, revealed a lead accumulation in the muscle tissue under the LOD. This result reflects an international publication from Sures. Overall, fish parasites can accumulate extremely high amounts of lead without being harmed by such amounts. Moreover, they are capable to act as bioindicator by confirming potential anthropogenic influences within an aquatic system.

6. Zusammenfassung

Im Rahmen dieser Masterarbeit wurden Schwermetallmessungen an einem Graphitrohr Atomabsorptionsspektrometer der Firma PerkinElmer® durchgeführt. Die zu untersuchenden Kompartimente setzten sich zusammen aus Sediment, Biofilm, Moos, Fische und etwaige Fischparasiten aus dem Wienfluss und der Schwechat.

Das neuerworbene Atomabsorptionsspektrometer wurde zu Beginn der Arbeit verwendet, um die instrumentellen Nachweisgrenzen der verschiedenen Schwermetalle wie Blei, Kupfer, Cadmium, Nickel und Chrom abzuklären.

Weiteres wurden Analysen von zertifizierten Referenzmaterialien des National Research Council Canada (NRCC) wie PACS-2 (Meeressediment), DORM-3 (Fischprotein) und DOLT-3 (Fischleber) durchgeführt, um die verwendeten Methoden zu validieren. Die Messung von bereits aufgeschlossenen Sedimentproben, Biofilm, Moos, Fische und Fischparasiten war der letzte experimentelle Teil dieser Arbeit. Die Sedimentresultate des Wienflusses zeigten eine besonders hohe Bleikonzentration im Stadtpark. Auch der Biofilm im Stadtpark wies einen hohen Bleiwert auf. Die Moosproben vom Wienfluss und der Schwechat zeigten ebenfalls eine Schwermetallanreicherung. Dies demonstriert die einzigartige Eigenschaft, dass Moos und Biofilm Schwermetalle anreichern und somit als Bioindikatoren herangezogen werden können. Die Fischresultate zeigten, dass sich in der Leber viel mehr Schwermetall anreichert, als im Muskelgewebe. Den höchsten Schwermetallanteil nahm das essentielle Kupfer im Lebergewebe ein. Sehr interessant war die Auswertung der Fischparasiten der Spezies *Pomphorhynchus laevis*, die einen extrem hohen Bleiwert aufwiesen und daher dem Fisch helfen, toxische Wirkungen diverser Schwermetalle wie Blei zu neutralisieren. Im Gegensatz dazu zeigten die befallenen Fische im Muskelgewebe sehr geringe Werte. Jene Fischmuskulatur, die den Parasiten mit der höchsten Bleikonzentration in sich trug, lag sogar unter der Blei Nachweisgrenze. Dieses Resultat findet sich auch in einer internationalen Publikationen von Sures wieder. Es hat sich gezeigt, dass Fischparasiten enorme Bleimengen zu sich nehmen können, ohne dass es ihnen schadet.

Sie können daher als nützliche Indikatoren verwendet werden, um einen etwaigen anthropogenen Zustand eines aquatischen Systems zu beschreiben.

7. Conclusion

Overall, it can be concluded that the high HM accumulation in regards to lead and copper in the sediment areas of Stadtpark is the result of several urban influences. In comparison to the concentrations of the other HM in sediments along the Wienfluss, the values of Nickel, Chromium and Cadmium were lower and in some cases they were even found under the background content. As it is observed, the Satdpark sediment accumulates high amounts of several HM, and the same can be concluded for biofilm, which accumulates them in very high amounts. Moss, on the other hand, does not accumulate such high concentrations of HM. According to the results obtained from HM accumulation in *P. fluviatilis*, *L. cephalus* and *G. gobio* in the Wienfluss and Schwechat River in comparison to international studies based on the influences of urban pollution in fishes, it can be stated that the fishes in these Austrian rivers contain smaller amounts of HM.

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9. Appendix

Table 16 Determination of Pb-content in sediment for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu) and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
WlSe	9.32	10.79	9.45	1.46	0.12	8.6	1.81	0.157	15	7.2	1:100	68.8
WlSe	10.49	11.87	10.67	1.38	0.17	12.8	1.38	0.178	15	39.2	1:10	33.1
WlSe	9.59	11.25	10.00	1.65	0.40	24.3	1.00	0.243	15	32.7	1:10	20.1
WlSe	9.21	10.76	9.39	1.55	0.18	11.7	1.13	0.132	15	37.3	1:10	42.4
WlSe	8.69	9.87	8.81	1.17	0.11	9.5	1.26	0.121	15	32.4	1:10	40.2
WlSe	9.72	11.11	9.88	1.38	0.16	11.7	1.42	0.166	15	43.1	1:10	38.9
PuSe	8.92	10.78	9.22	1.86	0.29	16.1	1.20	0.195	15	49.0	1:10	37.8
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.18	0.180	15	36.6	1:10	30.5
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.09	0.165	15	35.7	1:10	32.4
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.50	0.172	15	5.6	1:100	48.5
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.56	0.178	15	5.7	1:100	47.7
BaSe	10.72	12.27	11.06	1.55	0.34	22.3	1.11	0.249	15	24.9	1:10	15.0
BaSe	9.16	10.93	9.64	1.77	0.48	27.1	1.71	0.464	15	34.1	1:20	22.0
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.05	0.214	15	24.1	1:10	16.9
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.06	0.215	15	24.7	1:10	17.3
BaSe	9.58	11.46	10.02	1.88	0.44	23.5	1.10	0.259	15	47.3	1:10	27.4
BaSe	8.97	10.34	9.31	1.36	0.34	25.0	1.91	0.479	15	7.1	1:100	22.3

Table 17 Determination of Pb-content in sediment for sampling point Hietzing (Hi), Pilgrambridge (Pi) and Stadtpark (St)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
HiSe	9.37	10.88	9.87	1.50	0.49	32.9	1.75	0.576	15	47.5	1:100	123.7
HiSe	9.63	11.02	9.84	1.38	0.20	14.7	1.24	0.183	15	38.7	1:20	63.5
HiSe	9.58	10.74	9.82	1.15	0.23	20.6	1.03	0.213	15	29.4	1:20	41.4
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.56	0.462	15	18.6	1:100	60.3
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.44	0.425	15	48.0	1:100	169.3
PiSe	8.69	10.10	9.01	1.40	0.31	22.6	1.83	0.416	15	14.1	1:100	50.8
PiSe	10.79	12.20	11.01	1.41	0.21	15.5	1.74	0.270	15	13.4	1:100	74.3
PiSe	9.75	10.93	9.94	1.17	0.19	16.2	1.10	0.179	15	48.9	1:10	41.0
PiSe	9.70	11.11	9.95	1.41	0.25	18.0	1.05	0.190	15	52.6	1:10	41.5
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.38	0.310	15	8.8	1:100	42.6
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.34	0.302	15	20.2	1:100	100.4
StSe	10.75	12.53	11.36	1.77	0.60	34.2	1.33	0.457	15	25.2	1:100	82.6
StSe	9.80	11.38	10.16	1.58	0.36	23.0	1.44	0.331	15	18.0	1:100	81.5
StSe	9.32	10.81	10.18	1.48	0.85	57.6	1.12	0.649	15	21.8	1:1000	503.1
StSe	9.80	11.28	10.32	1.47	0.52	35.5	1.07	0.382	15	10.5	1:1000	410.0
StSe	10.49	12.34	11.31	1.85	0.82	44.2	2.09	0.925	15	10.7	1:100	17.3
StSe	10.79	12.90	11.30	2.11	0.51	24.4	1.89	0.464	15	11.2	1:10000	3619.8

Table 18 Determination of Pb-content in sediment for sampling point Agsbach (Ag) and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
AgSe	14.66	17.82	17.08	3.16	2.41	76.4	2.25	1.726	15	10.3	1:100	8.9
AgSe	10.61	12.81	12.16	2.20	1.54	70.2	2.09	1.474	15	7.8	1:100	7.9
AgSe	14.48	17.58	16.70	3.09	2.22	71.7	3.36	2.411	15	11.6	1:100	7.2
AgSe	11.00	13.89	13.03	2.88	2.02	70.3	3.41	2.399	15	12.8	1:100	8.0
AgSe	14.66	15.87	15.53	1.21	0.86	71.8	2.45	1.765	15	7.4	1:100	6.3
AgSe	10.61	11.96	11.59	1.35	0.98	72.7	1.36	0.992	15	4.9	1:100	7.3
AgSe	14.66	16.03	15.58	1.37	0.91	66.9	1.63	1.096	15	7.7	1:100	10.6
AgSe	10.62	12.06	11.63	1.43	1.01	70.4	1.31	0.923	15	6.6	1:100	10.7
ZaSe	14.65	17.60	16.29	2.95	1.64	55.7	1.74	0.970	15	8.4	1:100	13.0
ZaSe	10.60	11.90	11.17	1.29	0.56	43.8	2.01	0.883	15	6.8	1:100	11.6
ZaSe	14.65	17.21	15.93	2.55	1.28	50.0	1.72	0.863	15	17.4	1:100	30.3
ZaSe	10.60	11.90	11.18	1.29	0.57	44.6	1.73	0.775	15	16.1	1:100	31.1
ZaSe	51.19	53.66	52.15	2.46	0.96	39.0	1.39	0.544	15	11.9	1:100	32.7
ZaSe	51.76	56.07	53.47	4.31	1.71	39.8	2.97	1.182	15	19.9	1:100	25.3

Table 19 Determination of Pb-content in biofilm for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), Bauhaus (Ba) and Hietzing (Hi)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
WiBf	10.79	12.15	10.91	1.36	0.13	9.6	1.50	0.144	15	35.0	1:10	36.5
WiBf	9.96	11.52	10.05	1.56	0.08	5.7	1.78	0.102	15	52.9	—	7.8
WiBf	9.00	10.59	9.13	1.58	0.12	7.9	1.39	0.111	15	19.9	1:10	27.0
WiBf	9.63	11.49	9.78	1.86	0.15	8.1	2.32	0.188	15	35.9	1:10	28.7
WiBf	10.78	12.13	10.97	1.34	0.18	13.8	1.74	0.240	15	28.4	1:10	17.8
PuBf	9.59	10.69	9.70	1.09	0.10	9.5	1.01	0.097	15	13.3	1:10	20.5
BaBf	9.21	11.88	9.34	2.67	0.13	5.1	1.12	0.057	15	4.9	1:10	12.9
BaBf	9.72	11.15	9.87	1.42	0.14	10.2	1.28	0.130	15	10.3	1:10	11.8
BaBf	10.79	11.94	10.85	1.15	0.06	5.6	1.51	0.085	15	9.3	1:10	16.3
BaBf	9.63	12.01	9.82	2.38	0.19	8.2	2.10	0.172	15	23.8	1:100	207.1
BaBf	8.71	10.11	8.81	1.39	0.09	6.9	1.92	0.132	15	34.9	1:10	39.5
HiBf	9.76	11.04	9.86	1.27	0.09	7.8	1.28	0.100	15	23.3	1:10	35.0
HiBf	9.18	11.05	9.32	1.87	0.14	7.9	1.93	0.153	15	21.6	1:10	21.1
HiBf	8.38	10.02	8.56	1.63	0.17	10.7	1.24	0.133	15	20.4	1:10	23.0
HiBf	8.70	10.38	8.82	1.67	0.12	7.3	1.79	0.132	15	22.8	1:100	260.0
HiBf	10.72	12.78	10.87	2.06	0.16	7.8	1.69	0.132	15	19.5	1:10	22.2
HiBf	9.29	10.96	9.47	1.66	0.17	10.3	1.47	0.152	15	9.5	1:10	9.4

Table 20 Determination of Pb-content in biofilm for sampling point Pilgrambridge (Pi), Stadtpark (St), and Donaukanal (Do)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
PiBf	8.97	10.11	9.08	1.14	0.10	9.1	2.00	0.183	15	14.7	1:10	12.1
PiBf	10.49	12.12	10.80	1.63	0.30	18.9	1.28	0.244	15	21.2	1:10	13.1
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	2.10	0.292	15	13.9	1:10	7.2
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	1.58	0.219	15	12.8	1:10	8.8
PiBf	9.32	11.51	9.71	2.18	0.38	17.4	1.42	0.249	15	15.4	1:10	9.3
PiBf	9.70	11.07	9.91	1.37	0.20	15.2	1.35	0.206	15	41.9	1:10	30.5
StBf	9.96	11.53	10.11	1.56	0.14	9.2	1.34	0.125	15	10.5	1:10	12.7
StBf	9.25	10.87	9.32	1.61	0.06	3.9	1.98	0.077	15	10.4	1:10	20.1
StBf	9.51	11.97	9.88	2.45	0.36	15.0	1.95	0.293	15	19.5	1:100	100.1
StBf	9.37	11.46	9.69	2.08	0.31	15.1	1.82	0.275	15	12.0	1:100	65.2
StBf	8.69	10.81	8.77	2.11	0.07	3.6	1.34	0.048	15	4.8	1:10	14.9
StBf	8.76	10.11	8.89	1.35	0.13	9.8	1.69	0.166	15	9.5	1:1000	861.2
StBf	9.16	10.93	9.39	1.77	0.23	13.3	1.71	0.229	15	23.3	1:10	15.3
StBf	9.51	11.34	9.68	1.83	0.16	9.2	1.99	0.183	15	19.1	1:10	15.7
StBf	9.37	11.33	9.56	1.95	0.18	9.6	1.72	0.165	15	38.9	1:100	353.0
DoBf	10.78	12.80	11.00	2.01	0.22	10.9	1.32	0.145	15	17.8	1:10	18.3

Table 21 Determination of Pb-content in moss for sampling point Wienerwaldsee (WI), Purkersdorf (Pu), and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
WiMo	8.76	10.17	8.84	1.40	0.08	5.9	1.65	0.098	15	4.6	1:10	7.1
PuMo	9.70	10.97	9.78	1.27	0.08	6.9	1.28	0.088	15	48.9	—	8.3
PuMo	8.97	10.59	9.17	1.61	0.19	11.9	1.15	0.137	15	12.6	1:10	13.8
PuMo	8.38	10.30	8.54	1.91	0.15	8.1	7.90	0.639	15	23.0	1:10	5.4
PuMo	10.49	12.24	10.64	1.74	0.15	8.6	1.29	0.112	15	52.2	1:10	70.1
BaMo	10.49	12.07	10.75	1.58	0.26	16.5	1.35	0.225	15	15.7	1:10	10.4
BaMo	9.21	10.90	9.52	1.68	0.30	18.3	2.09	0.383	15	27.8	1:10	10.9

Table 22 Determination of Pb-content in biofilm for sampling point Agsbach (Ag), Baden (Ba), and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
AgBf	49.64	54.26	49.79	4.61	0.14	3.2	2.20	0.072	15	8.7	1:10	18.2
AgBf	51.75	53.63	51.81	1.87	0.06	3.2	2.61	0.084	15	2.3	1:10	4.0
BaBf	49.25	51.89	49.58	2.64	0.33	12.5	3.20	0.403	15	22.6	1:10	8.4
BaBf	49.65	51.45	49.91	1.80	0.26	14.8	2.31	0.343	15	13.5	1:10	5.9
AxBf	49.93	52.03	50.22	2.10	0.29	14.0	2.30	0.323	15	25.8	1:10	12.0
AxBf	49.93	52.05	50.17	2.12	0.23	11.3	2.31	0.261	15	7.0	1:10	4.0

Table 23 Determination of Pb-content in moss for sampling point Agsbach (Ag), and Cholerakapelle (Ch)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) d.w.
AgPf	49.64	52.51	49.84	2.87	0.19	6.9	2.20	0.152	15	6.2	1:10	6.1
AgPf	51.75	54.62	51.98	2.86	0.22	8.0	1.66	0.133	15	4.6	1:10	5.1
AgPf	49.27	50.74	49.33	1.46	0.06	4.1	2.74	0.112	15	10.1	1:10	13.5
ChPf	51.75	53.48	51.83	1.72	0.07	4.4	2.92	0.128	15	3.8	1:10	4.5
ChPf	49.27	52.43	50.25	3.16	0.97	30.9	1.89	0.587	15	10.6	1:10	2.7
ChPf	49.25	51.89	49.58	2.64	0.33	12.5	2.01	0.253	15	16.8	1:10	10.0

Table 24 Determination of Pb-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	1.10	15	< LOD	—	< LOD
***L. cephalus* (2)**	93.0	21.0	1.13	15	< LOD	—	< LOD
***L. cephalus* (3)**	84.0	20.5	1.20	15	< LOD	—	< LOD
***L. cephalus* (4)**	154.2	24.5	1.05	15	< LOD	—	< LOD
***L. cephalus* (5)**	78.5	20.0	1.31	15	< LOD	—	< LOD
***L. cephalus* (6)**	43.9	16.5	0.77	15	< LOD	—	< LOD
***L. cephalus* (7)**	35.5	15.5	0.99	15	< LOD	—	< LOD
***L. cephalus* (8)**	110.8	22.5	1.04	15	< LOD	—	< LOD
***L. cephalus* (9)**	26.1	14.3	0.85	15	< LOD	—	< LOD

Table 25 Determination of Pb-content in muscle tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	1.00	15	< LOD	—	< LOD
***P. fluviatilis* (2)**	65.2	17.3	1.50	15	< LOD	—	< LOD
***P. fluviatilis* (3)**	68.9	17.2	1.02	15	< LOD	—	< LOD

Table 26 Determination of Pb-content in liver tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	0.56	15	< LOD	—	< LOD
***L. cephalus* (2)**	93.0	21.0	0.69	15	< LOD	—	< LOD
***L. cephalus* (3)**	84.0	20.5	0.46	15	0.155	—	0.005
***L. cephalus* (4)**	154.2	24.5	0.99	15	< LOD	—	< LOD
***L. cephalus* (5)**	78.5	20.0	0.77	15	< LOD	—	< LOD
***L. cephalus* (6)**	43.9	16.5	0.39	15	1.222	—	0.047
***L. cephalus* (8)**	110.8	22.5	1.04	15	0.405	—	0.006
***L. cephalus* (9)**	26.1	14.3	0.23	15	0.146	—	0.009

Table 27 Determination of Pb-content in liver tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October.2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	0.56	15	< LOD	—	< LOD
***P. fluviatilis* (2)**	65.2	17.3	0.77	15	< LOD	—	< LOD
***P. fluviatilis* (3)**	68.9	17.2	1.01	15	< LOD	—	< LOD

Table 28 Determination of Pb-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Zwölfaxing October 2009)

Shortcut	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) w.w.
***L. cephalus* (1)**	1.13	10	< LOD	—	< LOD
***L. cephalus* (2)**	1.07	10	0.842	—	0.008
***L. cephalus* (4)**	2.12	20	< LOD	—	< LOD
***L. cephalus* (5)**	2.30	20	< LOD	—	< LOD
***L. cephalus* (6)**	1.63	10	0.216	—	0.001
***L. cephalus* (7)**	2.05	20	< LOD	—	< LOD
***L. cephalus* (8)**	1.02	10	0.226	—	0.002
***L. cephalus* (9)**	1.79	10	< LOD	—	< LOD
***L. cephalus* (11)**	1.89	20	0.364	—	0.004
***L. cephalus* (12)**	2.35	10	< LOD	—	< LOD
***L. cephalus* (13)**	2.19	10	0.590	—	0.003

Table 29 Determination of Pb-content in muscle tissue from the fish species *Gobio gobio* (caught Zwölfaxing October 2009)

Shortcut	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Pb-content (µg/g) w.w.
***G. gobio* (1)**	12.0	1.32	15	3.843	—	0.044
***G. gobio* (2)**	10.3	0.95	15	1.134	—	0.018
***G. gobio* (3)**	14.2	1.85	15	2.484	—	0.020
***G. gobio* (4)**	12.5	1.26	15	< LOD	—	< LOD
***G. gobio* (5)**	14.0	1.65	15	3.553	—	0.032
***G. gobio* (6)**	11.1	1.32	15	2.425	—	0.027
***G. gobio* (7)**	9.0	1.12	10	2.905	—	0.026
***G. gobio* (8)**	10.1	1.04	10	2.115	—	0.020

Table 30 Determination of Cu-content in sediment for sampling point Wienerwaldsee (WI), Purkersdorf (Pu) and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
WISe	9.32	10.79	9.45	1.46	0.12	8.6	1.81	0.157	15	13.3	1:100	127.2
WISe	10.49	11.87	10.67	1.38	0.17	12.8	1.38	0.178	15	6.7	1:100	56.4
WISe	9.59	11.25	10.00	1.65	0.40	24.3	1.00	0.243	15	48.1	1:100	29.6
WISe	9.21	10.76	9.39	1.55	0.18	11.7	1.13	0.132	15	11.2	1:100	127.5
WISe	8.69	9.87	8.81	1.17	0.11	9.5	1.26	0.121	15	6.0	1:100	74.4
WISe	9.72	11.11	9.88	1.38	0.16	11.7	1.42	0.166	15	7.2	1:100	64.6
PuSe	8.92	10.78	9.22	1.86	0.29	16.1	1.20	0.195	15	9.3	1:100	71.4
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.18	0.180	15	8.4	1:100	70.0
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.09	0.165	15	7.4	1:100	67.4
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.50	0.172	15	1.2	1:1000	108.7
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.56	0.178	15	1.3	1:1000	107.4
BaSe	10.72	12.27	11.06	1.55	0.34	22.3	1.11	0.249	15	51.1	1:10	30.7
BaSe	9.16	10.93	9.64	1.77	0.48	27.1	1.71	0.464	15	12.0	1:100	38.8
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.05	0.214	15	34.6	1:10	24.3
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.06	0.215	15	35.2	1:10	24.6
BaSe	9.58	11.46	10.02	1.88	0.44	23.5	1.10	0.259	15	10.6	1:100	61.1
BaSe	8.97	10.34	9.31	1.36	0.34	25.0	1.91	0.479	15	1.5	1:1000	46.5

Table 31 Determination of Cu-content in sediment for sampling point Hietzing (Hi), Pilgrambridge (Pi) and Stadtpark (St)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
HiSe	9.37	10.88	9.87	1.50	0.49	32.9	1.75	0.576	15	27.9	1:100	72.8
HiSe	9.63	11.02	9.84	1.38	0.20	14.7	1.24	0.183	15	8.2	1:100	67.1
HiSe	9.58	10.74	9.82	1.15	0.23	20.6	1.03	0.213	15	7.4	1:100	52.1
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.56	0.462	15	1.4	1:1000	44.8
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.44	0.425	15	2.2	1:1000	76.1
PiSe	8.69	10.10	9.01	1.40	0.31	22.6	1.83	0.416	15	24.1	1:100	86.9
PiSe	10.79	12.20	11.01	1.41	0.21	15.5	1.74	0.270	15	16.3	1:100	90.9
PiSe	9.75	10.93	9.94	1.17	0.19	16.2	1.10	0.179	15	5.8	1:100	48.7
PiSe	9.70	11.11	9.95	1.41	0.25	18.0	1.05	0.190	15	5.6	1:100	43.8
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.38	0.310	15	0.8	1:1000	40.4
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.34	0.302	15	1.7	1:1000	85.4
StSe	10.75	12.53	11.36	1.77	0.60	34.2	1.33	0.457	15	12.8	1:100	41.9
StSe	9.80	11.38	10.16	1.58	0.36	23.0	1.44	0.331	15	17.1	1:100	77.6
StSe	9.32	10.81	10.18	1.48	0.85	57.6	1.12	0.649	15	4.1	1:1000	94.0
StSe	9.80	11.28	10.32	1.47	0.52	35.5	1.07	0.382	15	1.4	1:1000	53.4
StSe	10.49	12.34	11.31	1.85	0.82	44.2	2.09	0.925	15	0.9	1:1000	15.0
StSe	10.79	12.90	11.30	2.11	0.51	24.4	1.89	0.464	15	16.0	1:1000	516.8

Table 32 Determination of Cu-content in sediment for sampling point Agsbach (Ag) and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
AgSe	14.66	17.82	17.08	3.16	2.41	76.4	2.25	1.726	15	17.3	1:100	15.0
AgSe	10.61	12.81	12.16	2.20	1.54	70.2	2.09	1.474	15	16.6	1:100	16.9
AgSe	14.48	17.58	16.70	3.09	2.22	71.7	3.36	2.411	15	20.6	1:100	12.8
AgSe	11.00	13.89	13.03	2.88	2.02	70.3	3.41	2.399	15	23.9	1:100	15.0
AgSe	14.66	15.87	15.53	1.21	0.86	71.8	2.45	1.765	15	13.3	1:100	11.3
AgSe	10.61	11.96	11.59	1.35	0.98	72.7	1.36	0.992	15	8.0	1:100	12.1
AgSe	14.66	16.03	15.58	1.37	0.91	66.9	1.63	1.096	15	10.3	1:100	14.1
AgSe	10.62	12.06	11.63	1.43	1.01	70.4	1.31	0.923	15	9.4	1:100	15.2
ZaSe	14.65	17.60	16.29	2.95	1.64	55.7	1.74	0.970	15	9.3	1:100	14.4
ZaSe	10.60	11.90	11.17	1.29	0.56	43.8	2.01	0.883	15	9.5	1:100	16.1
ZaSe	14.65	17.21	15.93	2.55	1.28	50.0	1.72	0.863	15	43.7	1:100	76.0
ZaSe	10.60	11.90	11.18	1.29	0.57	44.6	1.73	0.775	15	39.0	1:100	75.5
ZaSe	51.19	53.66	52.15	2.46	0.96	39.0	1.39	0.544	15	26.7	1:100	73.6
ZaSe	51.76	56.07	53.47	4.31	1.71	39.8	2.97	1.182	15	41.9	1:100	53.2

Table 33 Determination of Cu-content in biofilm for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), Bauhaus (Ba) and Hietzing (Hi)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
WiBf	10.79	12.15	10.92	1.36	0.13	9.6	1.50	0.144	15	8.6	1:100	89.5
WiBf	9.96	11.52	10.05	1.56	0.08	5.7	1.78	0.102	15	11.2	1:10	16.5
WiBf	9.00	10.59	9.13	1.58	0.12	7.9	1.39	0.111	15	50.3	1:10	68.1
WiBf	9.63	11.49	9.78	1.86	0.15	8.1	2.32	0.188	15	7.1	1:100	56.4
WiBf	10.78	12.13	10.97	1.34	0.18	13.8	1.74	0.240	15	7.3	1:100	45.7
PuBf	9.59	10.69	9.70	1.09	0.10	9.5	1.01	0.097	15	38.6	1:10	59.8
BaBf	9.21	11.88	9.34	2.67	0.13	5.1	1.12	0.057	15	12.3	1:10	32.1
BaBf	9.72	11.15	9.87	1.42	0.14	10.2	1.28	0.130	15	20.0	1:10	23.1
BaBf	10.79	11.94	10.85	1.15	0.06	5.6	1.51	0.085	15	28.9	1:10	51.0
BaBf	9.63	12.01	9.82	2.38	0.19	8.2	2.10	0.172	15	5.7	1:100	49.9
BaBf	8.71	10.11	8.81	1.39	0.09	6.9	1.92	0.132	15	5.5	1:100	62.8
HiBf	9.76	11.04	9.86	1.27	0.09	7.8	1.28	0.100	15	35.1	1:10	52.6
HiBf	9.18	11.05	9.32	1.87	0.14	7.9	1.93	0.153	15	49.0	1:10	47.9
HiBf	8.38	10.02	8.56	1.63	0.17	10.7	1.24	0.133	15	8.1	1:100	91.4
HiBf	8.70	10.38	8.82	1.67	0.12	7.3	1.79	0.132	15	15.4	1:1000	1752.3
HiBf	10.72	12.78	10.88	2.06	0.16	7.8	1.69	0.132	15	2.6	1:100	30.0
HiBf	9.29	10.96	9.47	1.66	0.17	10.3	1.47	0.152	15	1.4	1:100	13.5

Table 34 Determination of Cu-content in biofilm for sampling point Pilgrambridge (Pi), Stadtpark (St), and Donaukanal (Do)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
PiBf	8.97	10.11	9.08	1.14	0.10	9.1	2.00	0.183	15	36.1	1:10	29.6
PiBf	10.49	12.12	10.80	1.63	0.30	18.9	1.28	0.244	15	34.1	1:10	21.0
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	2.10	0.292	15	23.6	1:10	12.1
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	1.58	0.219	15	21.6	1:10	14.8
PiBf	9.32	11.51	9.71	2.18	0.38	17.4	1.42	0.249	15	2.5	1:100	15.2
PiBf	9.70	11.07	9.91	1.37	0.20	15.2	1.35	0.206	15	4.6	1:100	33.7
StBf	9.96	11.53	10.11	1.56	0.14	9.2	1.34	0.125	15	22.2	1:10	26.7
StBf	9.25	10.87	9.32	1.61	0.06	3.9	1.98	0.077	15	8.7	1:10	16.9
StBf	9.51	11.97	9.88	2.45	0.36	15.0	1.95	0.293	15	8.9	1:100	45.4
StBf	9.37	11.46	9.69	2.08	0.31	15.1	1.82	0.275	15	7.2	1:100	39.5
StBf	8.69	10.81	8.77	2.11	0.07	3.6	1.34	0.048	15	3.2	1:10	10.0
StBf	8.76	10.11	8.89	1.35	0.13	9.8	1.69	0.166	15	3.5	1:100	31.3
StBf	9.16	10.93	9.39	1.77	0.23	13.3	1.71	0.229	15	1.9	1:100	12.5
StBf	9.51	11.34	9.68	1.83	0.16	9.2	1.99	0.183	15	0.8	1:100	6.4
StBf	9.37	11.33	9.56	1.95	0.18	9.6	1.72	0.165	15	13.6	1:100	123.9
DoBf	10.78	12.80	11.00	2.01	0.22	10.9	1.32	0.145	15	32.8	1:10	33.9

Table 35 Determination of Cu-content in moss for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
WiMo	8.76	10.17	8.84	1.40	0.08	5.9	1.65	0.098	15	20.2	1:10	31.0
PuMo	9.70	10.97	9.78	1.27	0.08	6.9	1.28	0.088	15	17.0	1:10	29.0
PuMo	8.97	10.59	9.17	1.61	0.19	11.9	1.15	0.137	15	48.5	1:10	53.0
PuMo	8.38	10.30	8.54	1.91	0.15	8.1	7.90	0.639	15	5.9	1:100	13.9
PuMo	10.49	12.24	10.64	1.74	0.15	8.6	1.29	0.112	15	4.7	1:100	63.5
BaMo	10.49	12.07	10.75	1.58	0.26	16.5	1.35	0.225	15	37.2	1:10	24.8
BaMo	9.21	10.90	9.52	1.68	0.30	18.3	2.09	0.383	15	5.2	1:100	20.5

Table 36 Determination of Cu-content in biofilm for sampling point Agsbach (Ag), Baden (Ba), and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
AgBf	49.69	54.26	49.79	4.61	0.14	3.2	2.20	0.072	15	17.9	1:10	37.5
AgBf	51.75	53.63	51.81	1.87	0.06	3.2	2.61	0.084	15	7.6	1:10	13.5
BaBf	49.25	51.89	49.58	2.64	0.33	12.5	3.20	0.403	15	40.3	1:10	15.0
BaBf	49.65	51.45	49.91	1.80	0.26	14.8	2.31	0.343	15	38.3	1:10	16.7
AxBf	49.93	52.03	50.22	2.10	0.29	14.0	2.30	0.323	15	7.0	1:100	32.5
AxBf	49.93	52.05	50.17	2.12	0.23	11.3	2.31	0.261	15	21.8	1:10	12.5

Table 37 Determination of Cu-content in moss for sampling point Agsbach (Ag), and Cholerakapelle (Ch)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) d.w.
AgPf	49.64	52.51	49.84	2.87	0.19	6.9	2.20	0.152	15	16.9	1:10	16.7
AgPf	51.75	54.62	51.98	2.86	0.22	8.0	1.66	0.133	15	11.6	1:10	13.1
AgPf	49.27	50.74	49.33	1.46	0.06	4.1	2.74	0.112	15	25.8	1:10	34.4
ChPf	51.75	53.48	51.83	1.72	0.07	4.4	1.63	0.071	15	14.5	1:10	17.0
ChPf	49.27	52.43	50.25	3.16	0.97	30.9	1.89	0.587	15	33.9	1:10	8.7
ChPf	49.25	51.89	49.58	2.64	0.33	12.5	2.01	0.253	15	32.3	1:10	19.2

Table 38 Determination of Cu-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	1.10	15	23.3	—	0.32
***L. cephalus* (2)**	93.0	21.0	1.13	15	11.0	—	0.15
***L. cephalus* (3)**	84.0	20.5	1.20	15	15.7	—	0.20
***L. cephalus* (4)**	154.2	24.5	1.05	15	16.5	—	0.24
***L. cephalus* (5)**	78.5	20.0	1.31	15	15.9	—	0.18
***L. cephalus* (6)**	43.9	16.5	0.77	15	10.2	—	0.20
***L. cephalus* (7)**	35.5	15.5	0.99	15	22.8	—	0.35
***L. cephalus* (8)**	110.8	22.5	1.04	15	16.5	—	0.24
***L. cephalus* (9)**	26.1	14.3	0.85	15	14.4	—	0.25

Table 39 Determination of Cu-content in muscle tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	1.00	15	10.3	—	0.15
***P. fluviatilis* (2)**	65.2	17.3	1.50	15	10.1	—	0.10
***P. fluviatilis* (3)**	68.9	17.2	1.02	15	9.5	—	0.14

Table 40 Determination of Cu-content in liver tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	0.56	15	11.3	1:10	3.01
***L. cephalus* (2)**	93.0	21.0	0.69	15	11.1	1:100	24.15
***L. cephalus* (3)**	84.0	20.5	0.46	15	4.3	1:100	14.32
***L. cephalus* (4)**	154.2	24.5	0.99	15	7.0	1:100	10.63
***L. cephalus* (5)**	78.5	20.0	0.77	15	2.6	1:100	5.02
***L. cephalus* (6)**	43.9	16.5	0.39	15	15.2	1:10	5.88
***L. cephalus* (8)**	110.8	22.5	1.04	15	6.3	1:100	9.09
***L. cephalus* (9)**	26.1	14.3	0.23	15	7.4	1:10	4.73

Table 41 Determination of Cu-content in liver tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October.2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	0.56	15	0.8	1:100	2.06
***P. fluviatilis* (2)**	65.2	17.3	0.77	15	1.2	1:100	2.38
***P. fluviatilis* (3)**	68.9	17.2	1.01	15	6.5	1:100	9.63

Table 42 Determination of Cu-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Zwölfaxing October 2009)

Shortcut	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) w.w.
***L. cephalus* (1)**	1.13	10	24.0	—	0.21
***L. cephalus* (2)**	1.07	10	24.3	—	0.23
***L. cephalus* (4)**	2.12	20	42.6	—	0.40
***L. cephalus* (5)**	2.30	20	44.7	—	0.39
***L. cephalus* (6)**	1.63	10	35.8	—	0.22
***L. cephalus* (7)**	2.05	20	54.0	—	0.53
***L. cephalus* (8)**	1.02	10	20.0	—	0.20
***L. cephalus* (9)**	1.79	10	25.8	—	0.14
***L. cephalus* (11)**	1.89	20	36.3	—	0.39
***L. cephalus* (12)**	2.35	10	49.8	—	0.21
***L. cephalus* (13)**	2.19	10	38.8	—	0.18

Table 43 Determination of Cu-content in muscle tissue from the fish species *Gobio gobio* (caught Zwölfaxing October 2009)

Shortcut	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cu-content (µg/g) w.w.
***G. gobio* (1)**	12.0	1.32	15	48.3	—	0.55
***G. gobio* (2)**	10.3	0.95	15	27.8	—	0.44
***G. gobio* (3)**	14.2	1.85	15	7.1	—	0.58
***G. gobio* (4)**	12.5	1.26	15	33.8	—	0.40
***G. gobio* (5)**	14.0	1.65	15	44.9	—	0.41
***G. gobio* (6)**	11.1	1.32	15	43.0	—	0.49
***G. gobio* (7)**	9.0	1.12	10	49.2	—	0.44
***G. gobio* (8)**	10.1	1.04	10	42.4	—	0.41

Table 44 Determination of Cd-content in sediment for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu) and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
WlSe	9.32	10.79	9.45	1.46	0.12	8.6	1.81	0.157	15	0.14	1:100	1.38
WlSe	10.49	11.87	10.67	1.38	0.17	12.8	1.38	0.178	15	0.70	1:10	0.59
WlSe	9.59	11.25	10.00	1.65	0.40	24.3	1.00	0.243	15	0.37	1:10	0.23
WlSe	9.21	10.76	9.39	1.55	0.18	11.7	1.13	0.132	15	0.77	1:10	0.87
WlSe	8.69	9.87	8.81	1.17	0.11	9.5	1.26	0.121	15	0.33	1:10	0.41
WlSe	9.72	11.11	9.88	1.38	0.16	11.7	1.42	0.166	15	0.39	1:10	0.36
PuSe	8.92	10.78	9.22	1.86	0.29	16.1	1.20	0.195	15	0.58	1:10	0.44
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.18	0.180	15	0.45	1:10	0.37
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.09	0.165	15	0.40	1:10	0.36
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.50	0.172	15	0.68	1:10	0.59
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.56	0.178	15	0.74	1:10	0.62
BaSe	10.72	12.27	11.06	1.55	0.34	22.3	1.11	0.249	15	0.32	1:10	0.19
BaSe	9.16	10.93	9.64	1.77	0.48	27.1	1.71	0.464	15	0.74	1:10	0.24
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.05	0.214	15	0.38	1:10	0.27
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.06	0.215	15	0.27	1:10	0.19
BaSe	9.58	11.46	10.02	1.88	0.44	23.5	1.10	0.259	15	0.62	1:10	0.36
BaSe	8.97	10.34	9.31	1.36	0.34	25.0	1.91	0.479	15	0.90	1:10	0.28

Table 45 Determination of Cd-content in sediment for sampling point Hietzing (Hi), Pilgrambridge (Pi) and Stadtpark (St)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
HiSe	9.37	10.88	9.87	1.50	0.49	32.9	1.75	0.576	15	1.15	1:10	0.30
HiSe	9.63	11.02	9.84	1.38	0.20	14.7	1.24	0.183	15	0.44	1:10	0.36
HiSe	9.58	10.74	9.82	1.15	0.23	20.6	1.03	0.213	15	0.45	1:10	0.32
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.56	0.462	15	1.03	1:10	0.33
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.44	0.425	15	0.88	1:10	0.31
PiSe	8.69	10.10	9.01	1.40	0.31	22.6	1.83	0.416	15	1.26	1:10	0.46
PiSe	10.79	12.20	11.01	1.41	0.21	15.5	1.74	0.270	15	1.38	1:10	0.77
PiSe	9.75	10.93	9.94	1.17	0.19	16.2	1.10	0.179	15	0.39	1:10	0.32
PiSe	9.70	11.11	9.95	1.41	0.25	18.0	1.05	0.190	15	0.35	1:10	0.28
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.38	0.310	15	0.66	1:10	0.32
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.34	0.302	15	0.88	1:10	0.44
StSe	10.75	12.53	11.36	1.77	0.60	34.2	1.33	0.457	15	1.00	1:10	0.33
StSe	9.80	11.38	10.16	1.58	0.36	23.0	1.44	0.331	15	1.01	1:10	0.46
StSe	9.32	10.81	10.18	1.48	0.85	57.6	1.12	0.649	15	0.21	1:100	0.48
StSe	9.80	11.28	10.32	1.47	0.52	35.5	1.07	0.382	15	0.73	1:10	0.28
StSe	10.42	12.34	11.31	1.85	0.82	44.2	2.09	0.925	15	0.64	1:10	0.10
StSe	10.79	12.90	11.30	2.11	0.51	24.4	1.89	0.464	15	1.62	1:10	0.52

Table 46 Determination of Cd-content in sediment for sampling point Agsbach (Ag) and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
AgSe	14.66	17.82	17.08	3.16	2.41	76.4	2.25	1.72	15	0.71	1:10	0.06
AgSe	10.61	12.81	12.16	2.20	1.54	70.2	2.09	1.47	15	0.65	1:10	0.07
AgSe	14.48	17.58	16.70	3.09	2.22	71.7	3.36	2.41	15	0.95	1:10	0.06
AgSe	11.00	13.89	13.03	2.88	2.02	70.3	3.41	2.39	15	1.11	1:10	0.07
AgSe	14.66	15.87	15.53	1.21	0.86	71.8	2.45	1.76	15	0.66	1:10	0.06
AgSe	10.61	11.96	11.59	1.35	0.98	72.7	1.36	0.99	15	0.37	1:10	0.06
AgSe	14.66	16.03	15.58	1.37	0.91	66.9	1.63	1.09	15	0.54	1:10	0.07
AgSe	10.62	12.06	11.63	1.43	1.01	70.4	1.31	0.92	15	0.44	1:10	0.07
ZaSe	14.65	17.60	16.29	2.95	1.64	55.7	1.74	0.97	15	0.55	1:10	0.08
ZaSe	10.60	11.90	11.17	1.29	0.56	43.8	2.01	0.88	15	0.64	1:10	0.11
ZaSe	14.65	17.21	15.93	2.55	1.28	50.0	1.72	0.86	15	1.72	1:10	0.30
ZaSe	10.60	11.90	11.18	1.29	0.57	44.6	1.73	0.77	15	2.11	1:10	0.41
ZaSe	51.19	53.66	52.15	2.46	0.96	39.0	1.39	0.54	15	1.20	1:10	0.33
ZaSe	51.76	56.0	53.47	4.31	1.71	39.8	2.97	1.18	15	2.12	1:10	0.27

Table 47 Determination of Cd-content in biofilm for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), Bauhaus (Ba) and Hietzing (Hi)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
WiBf	10.79	12.15	10.92	1.36	0.13	9.6	1.50	0.144	15	0.42	1:10	0.44
WiBf	9.96	11.52	10.05	1.56	0.08	5.7	1.78	0.102	15	0.15	1:10	0.22
WiBf	9.00	10.59	9.13	1.58	0.12	7.9	1.39	0.111	15	0.39	1:10	0.53
WiBf	9.63	11.49	9.78	1.86	0.15	8.1	2.32	0.188	15	0.42	1:10	0.33
WiBf	10.78	12.13	10.97	1.34	0.18	13.8	1.74	0.240	15	0.46	1:10	0.29
PuBf	9.59	10.69	9.70	1.09	0.10	9.5	1.01	0.097	15	0.35	1:10	0.54
BaBf	9.21	11.88	9.34	2.67	0.13	5.1	1.12	0.057	15	0.24	1:10	0.62
BaBf	9.72	11.15	9.87	1.42	0.14	10.2	1.28	0.130	15	0.37	1:10	0.43
BaBf	10.79	11.94	10.85	1.15	0.06	5.6	1.51	0.085	15	0.44	1:10	0.78
BaBf	9.63	12.01	9.82	2.38	0.19	8.2	2.10	0.172	15	0.84	1:10	0.73
BaBf	8.71	10.11	8.81	1.39	0.09	6.9	1.92	0.132	15	0.38	1:10	0.42
HiBf	9.76	11.04	9.86	1.27	0.09	7.8	1.28	0.100	15	0.42	1:10	0.63
HiBf	9.18	11.05	9.32	1.87	0.14	7.9	1.93	0.153	15	0.68	1:10	0.67
HiBf	8.38	10.02	8.56	1.63	0.17	10.7	1.24	0.133	15	0.35	1:10	0.39
HiBf	8.70	10.38	8.82	1.67	0.12	7.3	1.79	0.132	15	0.76	1:10	0.87
HiBf	10.72	12.78	10.88	2.06	0.16	7.8	1.69	0.132	15	0.31	1:10	0.35
HiBf	9.29	10.96	9.47	1.66	0.17	10.3	1.47	0.152	15	0.18	1:10	0.17

Table 48 Determination of Cd-content in biofilm for sampling point Pilgrambridge (Pi), Stadtpark (St), and Donaukanal (Do)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
PiBf	8.97	10.11	9.08	1.14	0.10	9.1	2.00	0.183	15	0.34	1:10	0.28
PiBf	10.49	12.12	10.80	1.63	0.30	18.9	1.28	0.244	15	0.32	1:10	0.20
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	2.10	0.292	15	0.35	1:10	0.18
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	1.58	0.219	15	0.33	1:10	0.22
PiBf	9.32	11.51	9.71	2.18	0.38	17.4	1.42	0.249	15	0.25	1:10	0.15
PiBf	9.70	11.07	9.91	1.37	0.20	15.2	1.35	0.206	15	0.36	1:10	0.26
StBf	9.96	11.53	10.11	1.56	0.14	9.2	1.34	0.125	15	0.42	1:10	0.50
StBf	9.25	10.87	9.32	1.61	0.06	3.9	1.98	0.077	15	0.20	1:10	0.39
StBf	9.51	11.97	9.88	2.45	0.36	15.0	1.95	0.293	15	0.73	1:10	0.38
StBf	9.37	11.46	9.69	2.08	0.31	15.1	1.82	0.275	15	0.52	1:10	0.28
StBf	8.69	10.81	8.77	2.11	0.07	3.6	1.34	0.048	15	0.09	1:10	0.28
StBf	8.76	10.11	8.89	1.35	0.13	9.8	1.69	0.166	15	0.25	1:10	0.23
StBf	9.16	10.93	9.39	1.77	0.23	13.3	1.71	0.229	15	0.28	1:10	0.19
StBf	9.51	11.34	9.68	1.83	0.16	9.2	1.99	0.183	15	0.16	1:10	0.13
StBf	9.37	11.33	9.56	1.95	0.18	9.6	1.72	0.165	15	0.26	1:10	0.23
DoBf	10.78	12.80	11.00	2.01	0.22	10.9	1.32	0.145	15	0.26	1:10	0.27

Table 49 Determination of Cd-content in moss for sampling point Wienerwaldsee (WI), Purkersdorf (Pu), and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-con-tent (µg/g) d.w.
WiMo	8.76	10.17	8.84	1.40	0.08	5.9	1.65	0.098	15	0.16	1:10	0.25
PuMo	9.70	10.97	9.78	1.27	0.08	6.9	1.28	0.088	15	0.14	1:10	0.23
PuMo	8.97	10.59	9.17	1.61	0.19	11.9	1.15	0.137	15	0.37	1:10	0.41
PuMo	8.38	10.30	8.54	1.91	0.15	8.1	7.90	0.639	15	0.34	1:10	0.08
PuMo	10.49	12.24	10.64	1.74	0.15	8.6	1.29	0.112	15	0.27	1:10	0.36
BaMo	10.49	12.07	10.75	1.58	0.26	16.5	1.35	0.225	15	0.44	1:10	0.30
BaMo	9.21	10.90	9.52	1.68	0.30	18.3	2.09	0.383	15	0.42	1:10	0.17

Table 50 Determination of Cd-content in biofilm for sampling point Agsbach (Ag), Baden (Ba), and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
AgBf	49.64	54.26	49.79	4.61	0.14	3.2	2.20	0.072	15	0.23	1:10	0.49
AgBf	51.75	53.63	51.81	1.87	0.06	3.2	2.61	0.084	15	0.06	1:10	0.10
BaBf	49.25	51.89	49.58	2.64	0.33	12.5	3.20	0.403	15	0.39	1:10	0.15
BaBf	49.65	51.45	49.91	1.80	0.26	14.8	2.31	0.343	15	0.29	1:10	0.13
AxBf	49.93	52.03	50.22	2.10	0.29	14.0	2.30	0.323	15	0.42	1:10	0.20
AxBf	49.93	52.05	50.17	2.12	0.23	11.3	2.31	0.261	15	0.12	1:10	0.07

Table 51 Determination of Cd-content in moss for sampling point Agsbach (Ag), and Cholerakapelle (Ch)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) d.w.
AgPf	49.64	52.51	49.84	2.87	0.19	6.9	2.20	0.152	15	0.41	1:10	0.40
AgPf	51.75	54.62	51.98	2.86	0.22	8.0	1.66	0.133	15	0.25	1:10	0.28
AgPf	49.27	50.74	49.33	1.46	0.06	4.1	2.74	0.112	15	0.56	1:10	0.75
ChPf	51.75	53.48	51.83	1.72	0.07	4.4	1.63	0.071	15	0.25	1:10	0.30
ChPf	49.27	52.43	50.25	3.16	0.97	30.9	1.89	0.587	15	0.29	1:10	0.07
ChPf	49.25	51.89	49.58	2.64	0.33	12.5	2.01	0.253	15	0.25	1:10	0.15

Table 52 Determination of Cd-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	1.10	15	0.109	—	0.001
***L. cephalus* (2)**	93.0	21.0	1.13	15	0.132	—	0.002
***L. cephalus* (3)**	84.0	20.5	1.20	15	0.138	—	0.002
***L. cephalus* (4)**	154.2	24.5	1.05	15	0.202	—	0.003
***L. cephalus* (5)**	78.5	20.0	1.31	15	0.132	—	0.002
***L. cephalus* (6)**	43.9	16.5	0.77	15	<LOD	—	<LOD
***L. cephalus* (7)**	35.5	15.5	0.99	15	0.111	—	0.002
***L. cephalus* (8)**	110.8	22.5	1.04	15	0.219	—	0.003
***L. cephalus* (9)**	26.1	14.3	0.85	15	0.250	—	0.004

Table 53 Determination of Cd-content in muscle tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	1.00	15	0.264	—	0.004
***P. fluviatilis* (2)**	65.2	17.3	1.50	15	0.177	—	0.002
***P. fluviatilis* (3)**	68.9	17.2	1.02	15	0.114	—	0.002

Table 54 Determination of Cd-content in liver tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	0.56	15	0.126	—	0.003
***L. cephalus* (2)**	93.0	21.0	0.69	15	0.502	—	0.011
***L. cephalus* (3)**	84.0	20.5	0.46	15	0.302	—	0.010
***L. cephalus* (4)**	154.2	24.5	0.99	15	0.509	—	0.008
***L. cephalus* (5)**	78.5	20.0	0.77	15	0.341	—	0.007
***L. cephalus* (6)**	43.9	16.5	0.39	15	0.277	—	0.011
***L. cephalus* (8)**	110.8	22.5	1.04	15	0.986	—	0.014
***L. cephalus* (9)**	26.1	14.3	0.23	15	0.078	—	0.005

Table 55 Determination of Cd-content in liver tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October.2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	0.56	15	0.528	—	0.014
***P. fluviatilis* (2)**	65.2	17.3	0.77	15	0.432	—	0.008
***P. fluviatilis* (3)**	68.9	17.2	1.01	15	0.491	—	0.007

Table 56 Determination of Cd-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Zwölfaxing October 2009)

Shortcut	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) w.w.
***L. cephalus* (1)**	1.13	10	0.076	—	0.001
***L. cephalus* (2)**	1.07	10	0.198	—	0.002
***L. cephalus* (4)**	2.12	20	0.279	—	0.003
***L. cephalus* (5)**	2.30	20	0.350	—	0.003
***L. cephalus* (6)**	1.63	10	0.690	—	0.004
***L. cephalus* (7)**	2.05	20	0.175	—	0.002
***L. cephalus* (8)**	1.02	10	< LOD	—	< LOD
***L. cephalus* (9)**	1.79	10	< LOD	—	< LOD
***L. cephalus* (11)**	1.89	20	0.125	—	0.001
***L. cephalus* (12)**	2.35	10	0.108	—	0.001
***L. cephalus* (13)**	2.19	10	0.086	—	0.0004

Table 57 Determination of Cd-content in muscle tissue from the fish species *Gobio gobio* (caught Zwölfaxing October 2009)

Shortcut	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cd-content (µg/g) w.w.
***G. gobio* (1)**	12.0	1.32	15	0.106	—	0.001
***G. gobio* (2)**	10.3	0.95	15	< LOD	—	< LOD
***G. gobio* (3)**	14.2	1.85	15	0.144	—	0.001
***G. gobio* (4)**	12.5	1.26	15	0.166	—	0.002
***G. gobio* (5)**	14.0	1.65	15	0.132	—	0.001
***G. gobio* (6)**	11.1	1.32	15	0.139	—	0.002
***G. gobio* (7)**	9.0	1.12	10	0.221	—	0.002
***G. gobio* (8)**	10.1	1.04	10	0.142	—	0.001

Table 58 Determination of Ni-content in sediment for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu) and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
WlSe	9.32	10.79	9.45	1.46	0.12	8.6	1.81	0.157	15	3.7	1:100	35.7
WlSe	10.49	11.87	10.67	1.38	0.17	12.8	1.38	0.178	15	5.3	1:100	44.9
WlSe	9.59	11.25	10.00	1.65	0.40	24.3	1.00	0.243	15	33.6	1:10	20.7
WlSe	9.21	10.76	9.39	1.55	0.18	11.7	1.13	0.132	15	3.6	1:100	40.7
WlSe	8.69	9.87	8.81	1.17	0.11	9.5	1.26	0.121	15	4.4	1:100	54.3
WlSe	9.72	11.11	9.88	1.38	0.16	11.7	1.42	0.166	15	4.8	1:100	43.1
PuSe	8.92	10.78	9.22	1.86	0.29	16.1	1.20	0.195	15	4.4	1:100	33.8
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.18	0.180	15	3.9	1:100	32.2
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.09	0.165	15	3.6	1:100	32.6
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.50	0.172	15	5.7	1:100	49.6
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.56	0.178	15	5.1	1:100	42.9
BaSe	10.72	12.27	11.06	1.55	0.34	22.3	1.11	0.249	15	20.7	1:10	12.4
BaSe	9.16	10.93	9.64	1.77	0.48	27.1	1.71	0.464	15	6.2	1:100	20.0
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.05	0.214	15	23.6	1:10	16.5
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.06	0.215	15	25.9	1:10	18.1
BaSe	9.58	11.46	10.02	1.88	0.44	23.5	1.10	0.259	15	6.2	1:100	36.1
BaSe	8.97	10.34	9.31	1.36	0.34	25.0	1.91	0.479	15	8.1	1:100	25.4

Table 59 Determination of Ni-content in sediment for sampling point Hietzing (Hi), Pilgrambridge (Pi) and Stadtpark (St)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
HiSe	9.37	10.88	9.87	1.50	0.49	32.9	1.75	0.576	15	9.4	1:100	24.6
HiSe	9.63	11.02	9.84	1.38	0.20	14.7	1.24	0.183	15	3.8	1:100	31.1
HiSe	9.58	10.74	9.82	1.15	0.23	20.6	1.03	0.213	15	4.7	1:100	33.3
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.56	0.462	15	6.4	1:100	20.8
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.44	0.425	15	6.5	1:100	22.9
PiSe	8.69	10.10	9.01	1.40	0.31	22.6	1.83	0.416	15	5.4	1:100	19.5
PiSe	10.79	12.20	11.01	1.41	0.21	15.5	1.74	0.270	15	3.8	1:100	20.9
PiSe	9.75	10.93	9.94	1.17	0.19	16.2	1.10	0.179	15	2.9	1:100	24.3
PiSe	9.70	11.11	9.95	1.41	0.25	18.0	1.05	0.190	15	3.0	1:100	23.8
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.38	0.310	15	4.4	1:100	21.4
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.34	0.302	15	5.3	1:100	26.6
StSe	10.75	12.53	11.36	1.77	0.60	34.2	1.33	0.457	15	4.4	1:100	14.5
StSe	9.80	11.38	10.16	1.58	0.36	23.0	1.44	0.331	15	4.1	1:100	18.4
StSe	9.32	10.81	10.18	1.48	0.85	57.6	1.12	0.649	15	22.2	1:100	51.3
StSe	9.80	11.28	10.32	1.47	0.52	35.5	1.07	0.382	15	8.5	1:100	33.4
StSe	10.49	12.34	11.31	1.85	0.82	44.2	2.09	0.925	15	4.0	1:100	6.5
StSe	10.79	12.90	11.30	2.11	0.51	24.4	1.89	0.464	15	10.6	1:100	34.3

Table 60 Determination of Ni-content in sediment for sampling point Agsbach (Ag) and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
AgSe	14.66	17.82	17.08	3.16	2.41	76.4	2.25	1.726	15	24.5	1:100	21.3
AgSe	10.61	12.81	12.16	2.20	1.54	70.2	2.09	1.474	15	17.8	1:100	18.1
AgSe	14.48	17.58	16.70	3.09	2.22	71.7	3.36	2.411	15	21.7	1:100	13.5
AgSe	11.00	13.89	13.03	2.88	2.02	70.3	3.41	2.399	15	26.5	1:100	16.5
AgSe	14.66	15.87	15.53	1.21	0.86	71.8	2.45	1.765	15	15.9	1:100	13.5
AgSe	10.61	11.96	11.59	1.35	0.98	72.7	1.36	0.992	15	9.5	1:100	14.4
AgSe	14.66	16.03	15.58	1.37	0.91	66.9	1.63	1.096	15	12.5	1:100	17.2
AgSe	10.62	12.06	11.63	1.43	1.01	70.4	1.31	0.923	15	10.4	1:100	16.9
ZaSe	14.65	17.60	16.29	2.95	1.64	55.7	1.74	0.970	15	4.2	1:100	6.4
ZaSe	10.60	11.90	11.17	1.29	0.56	43.8	2.01	0.883	15	4.1	1:100	6.9
ZaSe	14.65	17.21	15.93	2.55	1.28	50.0	1.72	0.863	15	12.0	1:100	20.8
ZaSe	10.60	11.90	11.18	1.29	0.57	44.6	1.73	0.775	15	11.6	1:100	22.4
ZaSe	51.19	53.66	52.15	2.46	0.96	39.0	1.39	0.544	15	8.2	1:100	22.6
ZaSe	51.76	56.07	53.47	4.31	1.71	39.8	2.97	1.182	15	14.6	1:100	18.6

Table 61 Determination of Ni-content in biofilm for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), Bauhaus (Ba) and Hietzing (Hi)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-con-tent (µg/g) d.w.
WiBf	10.79	12.15	10.92	1.36	0.13	9.6	1.50	0.144	15	25.1	1:10	26.2
WiBf	9.96	11.52	10.05	1.56	0.08	5.7	1.78	0.102	15	14.8	1:10	21.7
WiBf	9.00	10.59	9.13	1.58	0.12	7.9	1.39	0.111	15	23.8	1:10	32.2
WiBf	9.63	11.49	9.78	1.86	0.15	8.1	2.32	0.188	15	30.7	1:10	24.6
WiBf	10.78	12.13	10.97	1.34	0.18	13.8	1.74	0.240	15	23.1	1:10	14.4
PuBf	9.59	10.69	9.70	1.09	0.10	9.5	1.01	0.097	15	15.0	1:10	23.2
BaBf	9.21	11.88	9.34	2.67	0.13	5.1	1.12	0.057	15	6.7	1:10	17.5
BaBf	9.72	11.15	9.87	1.42	0.14	10.2	1.28	0.130	15	10.7	1:10	12.3
BaBf	10.79	11.94	10.85	1.15	0.06	5.6	1.51	0.085	15	9.7	1:10	17.1
BaBf	9.63	12.01	9.82	2.38	0.19	8.2	2.10	0.172	15	22.0	1:10	19.1
BaBf	8.71	10.11	8.81	1.39	0.09	6.9	1.92	0.132	15	26.4	1:10	29.9
HiBf	9.76	11.04	9.86	1.27	0.09	7.8	1.28	0.100	15	16.5	1:10	24.7
HiBf	9.18	11.05	9.32	1.87	0.14	7.9	1.93	0.153	15	20.8	1:10	20.4
HiBf	8.38	10.02	8.56	1.63	0.17	10.7	1.24	0.133	15	14.2	1:10	16.0
HiBf	8.70	10.38	8.82	1.67	0.12	7.3	1.79	0.132	15	39.9	1:10	45.4
HiBf	10.72	12.78	10.88	2.06	0.16	7.8	1.69	0.132	15	10.0	1:10	11.4
HiBf	9.29	10.96	9.47	1.66	0.17	10.3	1.47	0.152	15	7.3	1:10	7.2

Table 62 Determination of Ni-content in biofilm for sampling point Pilgrambridge (Pi), Stadtpark (St), and Donaukanal (Do)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
PiBf	8.97	10.11	9.08	1.14	0.10	9.1	2.00	0.183	15	10.7	1:10	8.8
PiBf	10.49	12.12	10.80	1.63	0.30	18.9	1.28	0.244	15	11.9	1:10	7.3
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	2.10	0.292	15	9.5	1:10	4.9
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	1.58	0.219	15	9.2	1:10	6.3
PiBf	9.32	11.51	9.71	2.18	0.38	17.4	1.42	0.249	15	10.0	1:10	6.0
PiBf	9.70	11.07	9.91	1.37	0.20	15.2	1.35	0.206	15	14.5	1:10	10.5
StBf	9.96	11.53	10.11	1.56	0.14	9.2	1.34	0.125	15	12.3	1:10	6.7
StBf	9.25	10.87	9.32	1.61	0.060	3.9	1.98	0.077	15	12.8	1:10	15.4
StBf	9.51	11.97	9.88	2.45	0.36	15.0	1.95	0.293	15	3.4	1:10	6.6
StBf	9.37	11.46	9.69	2.08	0.31	15.1	1.82	0.275	15	32.2	1:10	16.5
StBf	8.69	10.81	8.77	2.11	0.07	3.6	1.34	0.048	15	1.1	1:10	3.6
StBf	8.76	10.11	8.89	1.35	0.13	9.8	1.69	0.166	15	7.8	1:10	7.1
StBf	9.16	10.93	9.39	1.77	0.23	13.3	1.71	0.229	15	5.7	1:10	3.7
StBf	9.51	11.34	9.68	1.83	0.16	9.2	1.99	0.183	15	3.2	1:10	2.7
StBf	9.37	11.33	9.56	1.95	0.18	9.6	1.72	0.165	15	9.3	1:10	8.4
DoBf	10.78	12.80	11.00	2.01	0.22	10.9	1.32	0.145	15	23.7	1:10	24.5

Table 63 Determination of Ni-content in moss for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
WiMo	8.76	10.17	8.84	1.40	0.08	5.9	1.65	0.098	15	9.9	1:10	15.2
PuMo	9.70	10.97	9.78	1.27	0.08	6.9	1.28	0.088	15	6.1	1:10	10.3
PuMo	8.97	10.59	9.17	1.61	0.19	11.9	1.15	0.137	15	16.5	1:10	18.0
PuMo	8.38	10.30	8.54	1.91	0.15	8.1	7.90	0.639	15	15.8	1:10	3.7
PuMo	10.49	12.24	10.64	1.74	0.15	8.6	1.29	0.112	15	11.0	1:10	14.7
BaMo	10.49	12.07	10.75	1.58	0.26	16.5	1.35	0.225	15	19.1	1:10	12.8
BaMo	9.21	10.90	9.52	1.68	0.30	18.3	2.09	0.383	15	24.3	1:10	9.5

Table 64 Determination of Ni-content in biofilm for sampling point Agsbach (Ag), Baden (Ba), and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
AgBf	49.64	54.26	49.79	4.61	0.14	3.2	2.20	0.072	15	19.9	1:10	41.6
AgBf	51.75	53.63	51.81	1.87	0.06	3.2	2.61	0.084	15	8.3	1:10	14.7
BaBf	49.25	51.89	49.58	2.64	0.33	12.5	3.20	0.403	15	28.0	1:10	10.4
BaBf	49.65	51.45	49.91	1.80	0.26	14.8	2.31	0.343	15	25.6	1:10	11.2
AxBf	49.93	52.03	50.22	2.10	0.29	14.0	2.30	0.323	15	27.4	1:10	12.7
AxBf	49.93	52.05	50.17	2.12	0.23	11.3	2.31	0.261	15	10.4	1:10	6.0

Table 65 Determination of Ni-content in moss for sampling point Agsbach (Ag), and Cholerakapelle (Ch)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) d.w.
AgPf	49.64	52.51	49.84	2.87	0.19	6.9	2.20	0.152	15	16.2	1:10	15.9
AgPf	51.75	54.62	51.98	2.86	0.22	8.0	1.66	0.133	15	10.5	1:10	11.9
AgPf	49.27	50.74	49.33	1.46	0.06	4.1	2.74	0.112	15	21.2	1:10	28.2
ChPf	51.75	53.48	51.83	1.72	0.07	4.4	1.63	0.071	15	9.7	1:10	11.4
ChPf	49.27	52.43	50.25	3.16	0.97	30.9	1.89	0.587	15	21.9	1:10	5.6
ChPf	49.25	51.89	49.58	2.64	0.33	12.5	2.01	0.253	15	21.9	1:10	13.0

Table 66 Determination of Ni-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	1.10	15	<LOD	—	<LOD
***L. cephalus* (2)**	93.0	21.0	1.13	15	<LOD	—	<LOD
***L. cephalus* (3)**	84.0	20.5	1.20	15	<LOD	—	<LOD
***L. cephalus* (4)**	154.2	24.5	1.05	15	<LOD	—	<LOD
***L. cephalus* (5)**	78.5	20.0	1.31	15	<LOD	—	<LOD
***L. cephalus* (6)**	43.9	16.5	0.77	15	<LOD	—	<LOD
***L. cephalus* (7)**	35.5	15.5	0.99	15	0.15	—	0.002
***L. cephalus* (8)**	110.8	22.5	1.04	15	<LOD	—	<LOD
***L. cephalus* (9)**	26.1	14.3	0.85	15	0.51	—	0.009

Table 67 Determination of Ni-content in muscle tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	1.00	15	0.23	—	0.003
***P. fluviatilis* (2)**	65.2	17.3	1.50	15	<LOD	—	<LOD
***P. fluviatilis* (3)**	68.9	17.2	1.02	15	<LOD	—	<LOD

Table 68 Determination of Ni-content in liver tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	0.56	15	0.68	—	0.018
***L. cephalus* (2)**	93.0	21.0	0.69	15	0.69	—	0.015
***L. cephalus* (3)**	84.0	20.5	0.46	15	0.66	—	0.022
***L. cephalus* (4)**	154.2	24.5	0.99	15	1.19	—	0.018
***L. cephalus* (5)**	78.5	20.0	0.77	15	0.84	—	0.016
***L. cephalus* (6)**	43.9	16.5	0.39	15	0.81	—	0.031
***L. cephalus* (8)**	110.8	22.5	1.04	15	1.29	—	0.019
***L. cephalus* (9)**	26.1	14.3	0.23	15	0.73	—	0.047

Table 69 Determination of Ni-content in liver tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October.2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	0.56	15	0.93	—	0.025
***P. fluviatilis* (2)**	65.2	17.3	0.77	15	1.00	—	0.020
***P. fluviatilis* (3)**	68.9	17.2	1.01	15	1.20	—	0.018

Table 70 Determination of Ni-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Zwölfaxing October 2009)

Shortcut	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) w.w.
***L. cephalus* (1)**	1.13	10	1.24	—	0.011
***L. cephalus* (2)**	1.07	10	0.56	—	0.005
***L. cephalus* (4)**	2.12	20	<LOD	—	<LOD
***L. cephalus* (5)**	2.30	20	<LOD	—	<LOD
***L. cephalus* (6)**	1.63	10	<LOD	—	<LOD
***L. cephalus* (7)**	2.05	20	<LOD	—	<LOD
***L. cephalus* (8)**	1.02	10	<LOD	—	<LOD
***L. cephalus* (9)**	1.79	10	<LOD	—	<LOD
***L. cephalus* (11)**	1.89	20	<LOD	—	<LOD
***L. cephalus* (12)**	2.35	10	<LOD	—	<LOD
***L. cephalus* (13)**	2.19	10	<LOD	—	<LOD

Table 71 Determination of Ni-content in muscle tissue from the fish species *Gobio gobio* (caught Zwölfaxing October 2009)

Shortcut	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Ni-content (µg/g) w.w.
***G. gobio* (1)**	12.0	1.32	15	3.32	—	0.038
***G. gobio* (2)**	10.3	0.95	15	1.00	—	0.016
***G. gobio* (3)**	14.2	1.85	15	14.30	—	0.116
***G. gobio* (4)**	12.5	1.26	15	4.07	—	0.049
***G. gobio* (5)**	14.0	1.65	15	24.09	—	0.219
***G. gobio* (6)**	11.1	1.32	15	11.07	—	0.126
***G. gobio* (7)**	9.0	1.12	10	5.10	—	0.046
***G. gobio* (8)**	10.1	1.04	10	13.64	—	0.131

Table 72 Determination of Cr-content in sediment for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu) and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
WlSe	9.32	10.79	9.45	1.46	0.12	8.6	1.81	0.157	15	1.41	1:1000	134.7
WlSe	10.49	11.87	10.67	1.38	0.17	12.8	1.38	0.178	15	1.39	1:1000	117.3
WlSe	9.59	11.25	10.00	1.65	0.40	24.3	1.00	0.243	15	1.15	1:1000	70.9
WlSe	9.21	10.76	9.39	1.55	0.18	11.7	1.13	0.132	15	1.25	1:1000	142.1
WlSe	8.69	9.87	8.81	1.17	0.11	9.5	1.26	0.121	15	1.30	1:1000	160.9
WlSe	9.72	11.11	9.88	1.38	0.16	11.7	1.42	0.166	15	1.71	1:1000	153.8
PuSe	8.92	10.78	9.22	1.86	0.29	16.1	1.20	0.195	15	1.44	1:1000	110.8
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.18	0.180	15	1.06	1:1000	88.4
PuSe	9.71	10.93	9.90	1.21	0.18	15.1	1.09	0.165	15	0.91	1:1000	82.3
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.50	0.172	15	1.55	1:1000	135.4
PuSe	9.06	10.30	9.20	1.23	0.14	11.4	1.56	0.178	15	1.64	1:1000	138.3
BaSe	10.72	12.27	11.06	1.55	0.34	22.3	1.11	0.249	15	7.00	1:100	42.1
BaSe	9.16	10.93	9.64	1.77	0.48	27.1	1.71	0.464	15	1.77	1:1000	57.3
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.05	0.214	15	7.43	1:100	52.1
BaSe	9.18	10.44	9.43	1.26	0.25	20.2	1.06	0.215	15	7.85	1:100	54.8
BaSe	9.58	11.46	10.02	1.88	0.44	23.5	1.10	0.259	15	1.72	1:1000	99.7
BaSe	8.97	10.34	9.31	1.36	0.34	25.0	1.91	0.479	15	2.40	1:1000	75.1

Table 73 Determination of Cr-content in sediment for sampling point Hietzing (Hi), Pilgrambridge (Pi) and Stadtpark (St)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
HiSe	9.37	10.88	9.87	1.50	0.49	32.9	1.75	0.576	15	3.29	1:1000	85.7
HiSe	9.63	11.02	9.84	1.38	0.20	14.7	1.24	0.183	15	1.10	1:1000	90.6
HiSe	9.58	10.74	9.82	1.15	0.23	20.6	1.03	0.213	15	1.19	1:1000	83.7
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.56	0.462	15	2.01	1:1000	65.3
HiSe	9.00	10.87	9.55	1.86	0.54	29.4	1.44	0.425	15	2.35	1:1000	83.0
PiSe	8.69	10.10	9.01	1.40	0.31	22.6	1.83	0.416	15	1.39	1:1000	50.2
PiSe	10.79	12.20	11.01	1.41	0.21	15.5	1.74	0.270	15	1.14	1:1000	63.4
PiSe	9.75	10.93	9.94	1.17	0.19	16.2	1.10	0.179	15	0.71	1:1000	59.3
PiSe	9.70	11.11	9.95	1.41	0.25	18.0	1.05	0.190	15	0.81	1:1000	63.6
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.38	0.310	15	1.11	1:1000	53.9
PiSe	9.96	11.29	10.26	1.33	0.29	22.4	1.34	0.302	15	1.63	1:1000	81.2
StSe	10.75	12.53	11.36	1.77	0.60	34.2	1.33	0.457	15	1.16	1:1000	38.1
StSe	9.80	11.38	10.16	1.58	0.36	23.0	1.44	0.331	15	1.13	1:1000	51.4
StSe	9.32	10.81	10.18	1.48	0.85	57.6	1.12	0.649	15	4.77	1:1000	110.3
StSe	9.80	11.28	10.32	1.47	0.52	35.5	1.07	0.382	15	2.23	1:1000	87.4
StSe	10.49	12.34	11.31	1.85	0.82	44.2	2.09	0.925	15	1.16	1:1000	18.8
StSe	10.79	12.90	11.30	2.11	0.51	24.4	1.89	0.464	15	3.38	1:1000	109.1

Table 74 Determination of Cr-content in sediment for sampling point Agsbach (Ag) and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
AgSe	14.66	17.82	17.08	3.16	2.41	76.4	2.25	1.726	15	5.50	1:1000	47.8
AgSe	10.61	12.81	12.16	2.20	1.54	70.2	2.09	1.474	15	4.25	1:1000	43.3
AgSe	14.48	17.58	16.70	3.09	2.22	71.7	3.36	2.411	15	5.27	1:1000	32.8
AgSe	11.00	13.89	13.03	2.88	2.02	70.3	3.41	2.399	15	6.30	1:1000	39.4
AgSe	14.66	15.87	15.53	1.21	0.86	71.8	2.45	1.765	15	3.95	1:1000	33.6
AgSe	10.61	11.96	11.59	1.35	0.98	72.7	1.36	0.992	15	2.23	1:1000	33.8
AgSe	14.66	16.03	15.58	1.37	0.91	66.9	1.63	1.096	15	3.37	1:1000	46.1
AgSe	10.62	12.06	11.63	1.43	1.01	70.4	1.31	0.923	15	2.71	1:1000	44.0
ZaSe	14.65	17.60	16.29	2.95	1.64	55.7	1.74	0.970	15	1.00	1:1000	15.4
ZaSe	10.60	11.90	11.17	1.29	0.56	43.8	2.01	0.883	15	1.05	1:1000	17.9
ZaSe	14.65	17.21	15.93	2.55	1.28	50.0	1.72	0.863	15	2.57	1:1000	44.8
ZaSe	10.60	11.90	11.18	1.29	0.57	44.6	1.73	0.775	15	2.62	1:1000	50.7
ZaSe	51.19	53.66	52.15	2.46	0.96	39.0	1.39	0.544	15	1.93	1:1000	53.2
ZaSe	51.76	56.07	53.47	4.31	1.71	39.8	2.97	1.182	15	3.58	1:1000	45.4

Table 75 Determination of Cr-content in biofilm for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), Bauhaus (Ba) and Hietzing (Hi)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
WiBf	10.79	12.15	10.92	1.36	0.13	9.6	1.50	0.144	15	7.38	1:100	77.0
WiBf	9.96	11.52	10.05	1.56	0.08	5.7	1.78	0.102	15	1.66	1:100	24.4
WiBf	9.00	10.59	9.13	1.58	0.12	7.9	1.39	0.111	15	6.38	1:100	86.3
WiBf	9.63	11.49	9.78	1.86	0.15	8.1	2.32	0.188	15	8.53	1:100	68.2
WiBf	10.78	12.13	10.97	1.34	0.18	13.8	1.74	0.240	15	8.48	1:100	52.9
PuBf	9.59	10.69	9.70	1.09	0.10	9.5	1.01	0.097	15	1.36	1:100	21.0
BaBf	9.21	11.88	9.34	2.67	0.13	5.1	1.12	0.057	15	1.12	1:100	29.3
BaBf	9.72	11.15	9.87	1.42	0.14	10.2	1.28	0.130	15	2.21	1:100	25.4
BaBf	10.79	11.94	10.85	1.15	0.06	5.6	1.51	0.085	15	2.36	1:100	41.6
BaBf	9.63	12.01	9.82	2.38	0.19	8.2	2.10	0.172	15	6.20	1:100	53.9
BaBf	8.71	10.11	8.81	1.39	0.09	6.9	1.92	0.132	15	6.58	1:100	74.6
HiBf	9.76	11.04	9.86	1.27	0.09	7.8	1.28	0.100	15	3.16	1:100	47.4
HiBf	9.18	11.05	9.32	1.87	0.14	7.9	1.93	0.153	15	4.43	1:100	43.3
HiBf	8.38	10.02	8.56	1.63	0.17	10.7	1.24	0.133	15	3.76	1:100	42.3
HiBf	8.70	10.38	8.82	1.67	0.12	7.3	1.79	0.132	15	11.03	1:100	125.7
HiBf	10.72	12.78	10.88	2.06	0.16	7.8	1.69	0.132	15	2.66	1:100	30.3
HiBf	9.29	10.96	9.47	1.66	0.17	10.3	1.47	0.152	15	2.41	1:100	23.9

Table 76 Determination of Cr-content in biofilm for sampling point Pilgrambridge (Pi), Stadtpark (St), and Donaukanal (Do)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
PiBf	8.97	10.11	9.08	1.14	0.10	9.1	2.00	0.183	15	1.61	1:100	13.2
PiBf	10.49	12.12	10.80	1.63	0.30	18.9	1.28	0.244	15	1.91	1:100	11.7
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	2.10	0.292	15	1.84	1:100	9.4
PiBf	9.29	10.75	9.50	1.45	0.20	13.9	1.58	0.219	15	1.52	1:100	10.4
PiBf	9.32	11.51	9.71	2.18	0.38	17.4	1.42	0.249	15	1.70	1:100	10.2
PiBf	9.70	11.07	9.91	1.37	0.20	15.2	1.35	0.206	15	3.72	1:100	27.1
StBf	9.96	11.53	10.11	1.56	0.14	9.2	1.34	0.125	15	1.16	1:100	13.9
StBf	9.25	10.87	9.32	1.61	0.06	3.9	1.98	0.077	15	0.87	1:100	16.8
StBf	9.51	11.97	9.88	2.45	0.36	15.0	1.95	0.293	15	5.36	1:100	27.5
StBf	9.37	11.46	9.69	2.08	0.31	15.1	1.82	0.275	15	4.25	1:100	23.2
StBf	8.69	10.81	8.77	2.11	0.07	3.6	1.34	0.048	15	0.29	1:100	9.2
StBf	8.76	10.11	8.89	1.35	0.13	9.8	1.69	0.166	15	2.06	1:100	18.7
StBf	9.16	10.93	9.39	1.77	0.23	13.3	1.71	0.229	15	1.22	1:100	8.0
StBf	9.51	11.34	9.68	1.83	0.16	9.2	1.99	0.183	15	0.61	1:100	5.0
StBf	9.37	11.33	9.56	1.95	0.18	9.6	1.72	0.165	15	2.12	1:100	19.3
DoBf	10.78	12.80	11.00	2.01	0.22	10.9	1.32	0.145	15	4.78	1:100	49.4

Table 77 Determination of Cr-content in moss for sampling point Wienerwaldsee (Wl), Purkersdorf (Pu), and Bauhaus (Ba)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sam-ple d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
WiMo	8.76	10.17	8.84	1.40	0.08	5.9	1.65	0.098	15	1.90	1:100	29.2
PuMo	9.70	10.97	9.78	1.27	0.08	6.9	1.28	0.088	15	0.94	1:100	16.0
PuMo	8.97	10.59	9.17	1.61	0.19	11.9	1.15	0.137	15	2.19	1:100	23.9
PuMo	8.38	10.30	8.54	1.91	0.15	8.1	7.90	0.639	15	4.29	1:100	10.1
PuMo	10.49	12.24	10.64	1.74	0.15	8.6	1.29	0.112	15	2.37	1:100	31.8
BaMo	10.49	12.07	10.75	1.58	0.26	16.5	1.35	0.225	15	2.83	1:100	18.8
BaMo	9.21	10.90	9.52	1.68	0.30	18.3	2.09	0.383	15	4.29	1:100	16.8

Table 78 Determination of Cr-content in biofilm for sampling point Agsbach (Ag), Baden (Ba), and Zwölfaxing (Za)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
AgBf	49.64	54.26	49.79	4.61	0.14	3.2	2.20	0.072	15	4.74	1:100	99.1
AgBf	51.75	53.63	51.81	1.87	0.06	3.2	2.61	0.084	15	1.89	1:100	33.6
BaBf	49.25	51.89	49.58	2.64	0.33	12.5	3.20	0.403	15	7.30	1:100	27.2
BaBf	49.65	51.45	49.91	1.80	0.26	14.8	2.31	0.343	15	5.73	1:100	25.0
AxBf	49.93	52.03	50.22	2.10	0.29	14.0	2.30	0.323	15	5.95	1:100	27.7
AxBf	49.93	52.05	50.17	2.12	0.23	11.3	2.31	0.261	15	1.67	1:100	9.6

Table 79 Determination of Cr-content in moss for sampling point Agsbach (Ag), and Cholerakapelle (Ch)

Shortcut	Empty crucible (g)	Gross crucible (g)	Net Crucible (g)	Sample w.w. (g)	Sample d.w. (g)	% d.w. to w.w.	Weight portion for digestion	D.w. for digestion	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) d.w.
AgPf	49.64	52.51	49.84	2.87	0.19	6.9	2.20	0.152	15	2.05	1:100	20.2
AgPf	51.75	54.62	51.98	2.86	0.22	8.0	1.66	0.133	15	1.44	1:100	16.3
AgPf	49.27	50.74	49.33	1.46	0.06	4.1	2.74	0.112	15	1.76	1:100	24.9
ChPf	51.75	53.48	51.83	1.72	0.07	4.4	1.63	0.071	15	3.48	1:100	46.4
ChPf	49.27	52.43	50.25	3.16	0.97	30.9	1.89	0.587	15	1.12	1:100	13.1
ChPf	49.25	51.89	49.58	2.64	0.33	12.5	2.01	0.253	15	1.83	1:100	38.6

Table 80 Determination of Cr-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	1.10	15	1.36	—	0.02
***L. cephalus* (2)**	93.0	21.0	1.13	15	3.44	—	0.05
***L. cephalus* (3)**	84.0	20.5	1.20	15	2.29	—	0.03
***L. cephalus* (4)**	154.2	24.5	1.05	15	1.24	—	0.02
***L. cephalus* (5)**	78.5	20.0	1.31	15	1.12	—	0.01
***L. cephalus* (6)**	43.9	16.5	0.77	15	0.76	—	0.01
***L. cephalus* (7)**	35.5	15.5	0.99	15	3.36	—	0.05
***L. cephalus* (8)**	110.8	22.5	1.04	15	3.68	—	0.05
***L. cephalus* (9)**	26.1	14.3	0.85	15	3.24	—	0.06

Table 81 Determination of Cr-content in muscle tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution-factor	Cr-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	1.00	15	2.52	—	0.04
***P. fluviatilis* (2)**	65.2	17.3	1.50	15	3.38	—	0.03
***P. fluviatilis* (3)**	68.9	17.2	1.02	15	1.12	—	0.02

Table 82 Determination of Cr-content in liver tissue from the fish species *Leuciscus cephalus* (caught Purkersdorf October 2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) w.w.
***L. cephalus* (1)**	41.2	6.5	0.56	15	1.10	1:10	0.29
***L. cephalus* (2)**	93.0	21.0	0.69	15	1.28	1:10	0.28
***L. cephalus* (3)**	84.0	20.5	0.46	15	1.55	1:10	0.51
***L. cephalus* (4)**	154.2	24.5	0.99	15	2.35	1:10	0.36
***L. cephalus* (5)**	78.5	20.0	0.77	15	1.26	1:10	0.25
***L. cephalus* (6)**	43.9	16.5	0.39	15	0.93	1:10	0.36
***L. cephalus* (8)**	110.8	22.5	1.04	15	1.92	1:10	0.28
***L. cephalus* (9)**	26.1	14.3	0.23	15	0.75	1:10	0.48

Table 83 Determination of Cr-content in liver tissue from the fish species *Perca fluviatilis* (caught Purkersdorf October.2012)

Shortcut	Total weight (g)	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution-factor	Cr-content (µg/g) w.w.
***P. fluviatilis* (1)**	71.8	17.8	0.56	15	1.66	1:10	0.44
***P. fluviatilis* (2)**	65.2	17.3	0.77	15	2.03	1:10	0.40
***P. fluviatilis* (3)**	68.9	17.2	1.01	15	2.43	1:10	0.36

Table 84 Determination of Cr-content in muscle tissue from the fish species *Leuciscus cephalus* (caught Zwölfaxing October 2009)

Shortcut	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) w.w.
***L. cephalus* (1)**	1.13	10	1.94	1:10	0.17
***L. cephalus* (2)**	1.07	10	1.93	1:10	0.18
***L. cephalus* (4)**	2.12	20	0.66	1:10	0.06
***L. cephalus* (5)**	2.30	20	1.72	1:10	0.15
***L. cephalus* (6)**	1.63	10	0.34	1:10	0.02
***L. cephalus* (7)**	2.05	20	0.83	1:10	0.08
***L. cephalus* (8)**	1.02	10	0.22	1:10	0.02
***L. cephalus* (9)**	1.79	10	0.24	1:10	0.01
***L. cephalus* (11)**	1.89	20	0.26	1:10	0.03
***L. cephalus* (12)**	2.35	10	1.22	1:10	0.05
***L. cephalus* (13)**	2.19	10	1.27	1:10	0.06

Table 85 Determination of Cr-content in muscle tissue from the fish species *Gobio gobio* (caught Zwölfaxing October 2009)

Shortcut	Total length (cm)	W.w. for digestion (g)	Total digestion volume (mL)	Measurement (µg/L)	Dilution factor	Cr-content (µg/g) w.w.
***G. gobio* (1)**	12.0	1.32	15	2.85	—	0.03
***G. gobio* (2)**	10.3	0.95	15	2.20	—	0.03
***G. gobio* (3)**	14.2	1.85	15	3.06	—	0.02
***G. gobio* (4)**	12.5	1.26	15	1.28	—	0.02
***G. gobio* (5)**	14.0	1.65	15	1.90	—	0.02
***G. gobio* (6)**	11.1	1.32	15	1.51	—	0.02
***G. gobio* (7)**	9.0	1.12	10	7.36	—	0.07
***G. gobio* (8)**	10.1	1.04	10	1.66	—	0.02

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9.3. Abbreviations

AAS	Atomic Absorption Spectrometry
CP	Ceruloplasmin
DOLT-3	Dogfish liver certified reference material
DORM-3	Fish protein certified reference material
d.w.	dry weight
GFAAS	Graphite Furnace Atomic Absorption Spectrometry
GIT	Gastrointestinal tract
HCL	Hollow cathode lamp
HM	Heavy metal
LOD	Limit of detection
MT	Metallothionein
NRCC	National Research Council Canada
PACS-2	Marine sediment certified reference material
RDA	Recommended dietary allowance
SD	Standard deviation
THGA	Transversely heated graphite atomizer
w.w.	wet weight
$\dot{x}_B$	Mean of blank values

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