Certified reference materials for organic contaminants for use in monitoring of the aquatic environment

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Over the last three decades organic contaminants have been of increasing importance in environmental monitoring. Dioxins, furans, polychlorinated biphenyls and organochlorine pesticides have determined the environmental research agenda. This has led to an increasing demand for certified reference materials (CRMs). However, CRMs have only been made available in limited numbers, as the production and certification of CRMs is normally a relatively slow process. This paper gives an overview of the available CRMs for biota and sediments for these contaminants and the developments in their quality.

Keywords: Certified reference materials; PCBs; Dioxins; Pesticides; Chlorinated benzenes; Organotin; PAHs; Environmental monitoring

1. Introduction

The analysis of organic contaminants such as polychlorinated dibenzo-*p*-dioxins (PCDDS), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), chlorinated benzenes, and organochlorine pesticides in environmental matrices is complex. The contaminants are often complex mixtures consisting of many different congeners. A determination of the total concentration of, for example, PCBs leads to significant errors as, due to weathering effects and metabolism, the patterns in the environmental samples are different from those in the technical mixtures. A congener-specific approach is therefore desirable, as only then can possible toxic congeners be specifically determined. However, chromatographic separation is often insufficient to offer a full separation of all congeners present. In addition, the environmental matrices are relatively difficult to handle. All these factors make the analysis of organic contaminants in environmental samples rather complicated. Laboratories performing this type of analysis and trying to cope with the high degree of analytical difficulty are obviously in need of a good quality control system. International monitoring programmes, which include the analysis of many of these organic contaminants have regularly stressed the need for a good comparability of the laboratories [1]. Consequently, for many years there has been a continuous request for reliable certified reference materials (CRMs). Although the production of CRMs for this field has increased, the available number of CRMs is still too small to cover the needs of the laboratories [2,3].

One of the first initiatives to develop CRMs for PCBs in Europe was taken by the Community Bureau of Reference of the European Union (BCR). In the mid 1980s a programme of stepwise designed interlaboratory studies was started, finally resulting in the production of two CRMs for PCBs: PCB in cod liver oil (CRM 349) and PCBs in mackerel oil (CRM 350) [4]. This approach to improve the agreement between laboratories using different methods was also used in the ICES/IOC/OSPARCOM PCB interlaboratory study, in which over 60 laboratories participated and which was very successful in improving the performance of participating [5–7]. Later several laboratories involved in the ICES/IOC/OSPARCOM study and the BCR work initiated the QUASIMEME programme (Quality Assurance of Information for Marine Environmental Monitoring in

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0165-9936/01/$ – see front matter
PII: S0165-9936(00)00079-0

Table 1
RMs for hydrocarbons in biota

Code	SRM 1974a	SRM 2974	SRM 2977	SRM 2978	140/OC
Organisation	SRM NIST[2]	SRM NIST[2]	SRM NIST[2]	SRM NIST[2]	IAEA[2]
Country of origin	USA	USA	USA	USA	Monaco
Matrix	Mussel tissue	Mussel tissue	Mussel tissue	Mussel tissue	Fucus (sea plant homogenate)
Units	μg/kg	μg/kg	μg/kg	μg.kg	μg/kg
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	±95% CI	±95% CI	±95% CI	±95% CI	95% CI
Units of issue	3×15 g	8 g	10 g	10 g	30 g
Form	Frozen tissue	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried and micronised
Resolved aliphatics					*13 000 (6400–24 000)
Unresolved aliphatics					*26 000 (12 000–48 000)
Total aliphatics					27 000 (25 000–42 000)
n-C14	*83.8±3.0				
n-C15	*108±12				
n-C16	*161±28				
n-C17	*280±57				890 (300–1300)
n-C18	*153±17				99 (45–140)
n-C19	*40.4±1.1				
n-C20	*65.1±6.0				
n-C22	*46.7±1.9				
n-C24	*57.2±5.7				
n-C26	*49.3±6.3				
n-C28	*64.5±3.3				
n-C30	*47.8±7.3				
n-C32	*55.9±4.2				
n-C34	*28.5±1.9				
Pristane	*74.1±5.8				50 (15–69)
Phytane	*56.9±6.8				56 (25–100)
Sum alkanes (C14–C34)					11 000 (5600–21 000)
Total aromatics					*5800 (750–16 000)
Resolved aromatics					*350 (150–500)
Unresolved aromatics					*8100 (3900–17 000)
Acenaphthene	*3.15±0.26	*2.74±0.52	*4.2±0.4	*6±2	*3.4 (3.3–7.0)
Acenaphthylene	*5.25±0.38	*4.60±0.88		*4±1	
Anthracene	6.1±1.7	6.1±1.7	*8±4	*5.4±2.2	14 (4–93)
Anthranene	*1.15±0.31	*1.15±0.31			
Benz[a]anthracene	32.5±4.7	32.5±4.8	20.34±0.78	*25±7	25 (14–32)
Benzo[b]chrysene	*1.60±0.15		1.07±0.15	*2.1±0.4	
Benzo[a]fluoranthene	*4.0±1.9	*4.0±1.9			
Benzo[b]fluoranthene	46.4±3.7	46.4±4.0	11.01±0.28	*58±15	*37 (33–37)
Benzo[j]fluoranthene	*20.5±1.7	*20.5±1.8	*4.6±0.2	*23±2	
Benzo[k]fluoranthene	20.18±0.84	20.2±1.0	*4±1	24.1±3.4	19 (15–27)
Benzo[ghi]fluoranthene	*28.3±5.5				
Benzo[ghi]perylene	22.0±2.2	22.0±2.3	9.53±0.43	19.7±4.4	20 (17–35)
Benzo[c]phenanthrene	*19.5±6.7		*9.4±0.3	*31±2	
Benzo[a]pyrene	15.63±0.65	15.63±0.80	8.35±0.72	*7±3	20 (16–22)
Benzo[e]pyrene	84.0±1.9	84.0±3.2	13.1±1.1	89.3±6.3	26 (19–33)
Biphenyl	*5.11±0.32	*4.68±0.56	*6.8±0.6	*8±1	
Chrysene	44.2±2.3	44.2±2.7	*49±2	*59±10	40 (25–49)
Dibenz[a,h]anthracene			1.41±0.19		*4.5 (2.6–160)
Dibenz[a,h]anthracene/dibenz[a,c]anthracene	*3.00±0.20	*3.00±0.16	*2.0±0.2	*3.5±0.5	
Dibenz[a,j]anthracene	*1.247±0.075	*1.247±0.084			
Fluoranthene	163.7±9.1	163.7±10.3	38.7±1.0	166±12	88 (57–110)
Fluorene	*5.72±0.91	*4.69±0.34	10.24±0.43	*7±1	*6.5 (4.6–1600)
Indeno[1,2,3-cd]pyrene	14.2±2.8	14.2±2.8	4.84±0.81	12.2±2.9	33 (20–53)
1-Methylnaphthalene	*5.3±1.8	*3.47±0.85	*16±5	*21±5	*13 (6.5–15)
2-Methylnaphthalene	*10.2±1.5	*6.48±0.85	*18±5	*23±4	*16 (9–23)

(Continued on next page)

Table 1 (*continued*)

Code	SRM 1974a	SRM 2974	SRM 2977	SRM 2978	140/OC
1-Methylphenanthrene	*10.5 ± 4.8	*10.5 ± 4.8	*44 ± 2	*6.8 ± 0.1	11 (9–14)
2-Methylphenanthrene	*20.6 ± 8.0	*20.6 ± 8.0	*43 ± 1		19 (15–40)
3-Methylphenanthrene	*13.5 ± 9.7	*13.5 ± 9.7	*44.2 ± 0.4		
4-Methylphenanthrene/ 9-methylphenanthrene	*14.7 ± 9.2	*14.7 ± 9.2	*36 ± 2		
Naphthalene	23.5 ± 4.4	*9.63 ± 0.61	*19 ± 5	*31 ± 6	17 (9–43)
Perylene	7.68 ± 0.27	7.68 ± 0.35	3.50 ± 0.76	4.09 ± 0.32	*5 (2.5–9.8)
Phenanthrene	22.2 ± 2.4	22.2 ± 2.5	35.1 ± 3.8	*74 ± 7	76 (40–110)
Picene			2.29 ± 0.27	*4.5 ± 0.5	
Pyrene	151.6 ± 6.6	151.6 ± 8.0	78.9 ± 3.5	256 ± 21	67 (46–79)
Triphenylene	50.7 ± 5.9	50.7 ± 6.1	*39 ± 1	*63 ± 9	
UVF chrysene					*3500 (1200–5400)
UVF ROPME oil					*29 000 (11 000–39 000)

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.

[1]The following comments apply to these tables: the compiled tables are for information. Although every effort has been made to ensure that these tables are accurate, users of CRMs should consult vendors for full and accurate information; certified calibration materials and standards are not included; these tables do not purport to be complete and all the CRMs listed may not be commercially available; methyl mercury is not considered as an organic contaminant for the purposes of this list.

[2]NIST: USA National Institute of Standards and Technology. IAEA: International Atomic Energy Agency. BCR: EC Bureau of Community Reference, now EC Institute for Reference Materials and Measurements (IRMM). NRC: Canada National Research Council, Institute for National Measurement Standards (INMS). NWRI: National Water Research Institute, Environment Canada. CIL: Cambridge Isotope Laboratories, USA. NIES: National Institute for Environmental Standards, Environment Agency, Japan; LGC: Laboratory of the Government Chemist.

Europe), which started as a European research project, but later continued on its own as a proficiency testing scheme [8]. This QUASIMEME programme not only includes organic contaminants, but also trace metals, nutrients and many other parameters which are relevant in marine environmental monitoring. Meanwhile, the IAEA (International Atomic Energy Agency) had conducted several interlaboratory studies which resulted in a number of CRMs. Other developments took place in the USA and Canada and also in Japan, resulting in a number of CRMs for organic contaminants which will be discussed below.

The criteria used by the organisations responsible for producing CRMs are sometimes different and are often subject of debate. One of the best definitions of a CRM is presumably the following: a CRM is a reference material (RM), one or more properties of which are certified, with a stated uncertainty, by a technically valid procedure, which are traceable to a stated reference and accompanied by a certificate or other documentation issued by an accreditation body, to be used for the evaluation of the method(s) used by the laboratory [9]. Not all CRMs discussed below comply with this definition. Some materials were just 'certified' as a result of an interlaboratory study only. Obviously, that did not include a technically valid procedure. Such materials should not be confused with CRMs which have been submitted to a very thorough process of certification by expert laboratories only followed by an extensive technical discussion. Laboratories should inform themselves about the background of available CRMs before they buy these relatively expensive materials. If a CRM is bought which has e.g. relatively wide uncertainties for a number of parameters, this could even be counter-productive as the laboratory might soon conclude that their methods comply with the certified values whereas in reality the results produced are only at one end of the wide uncertainty range and therefore relatively far away from the target value. Awaiting a definition of minimum requirements for the production of CRMs and the registration and accreditation of producers, laboratories should be very critical when buying and using the available CRMs. This is particularly true for the field of organic contaminants as errors can easily be made, and uncertainty ranges may soon become relatively wide.

Table 2
RMs for chlorinated pesticides in biota

	SRM 1974a	SRM 1588a	SRM 1945	SRM 2974	SRM 2977	SRM 2978	140/OC	BCR 598
Organisation	SRM NIST	SRM NIST	SRM NIST	SRM NIST	SRM NIST	SRM NIST	IAEA	BCR[2]
Country of origin	USA	USA	USA	USA	USA	USA	Monaco	EC
Matrix	Mussel tissue	Cod liver oil	Whale blubber	Mussel tissue	Mussel tissue	Mussel tissue	Fucus (sea plant homogenate)	Cod liver oil
Units	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
As	Dry weight	Wet weight	Wet weight	Dry weight	Dry weight	Dry weight	Dry weight	Wet weight
[±] expressed as	±95% CI	±95% CI	±95% CI	±95% CI	±95% CI	±95% CI	95% CI	95% CI
Units of issue	3×15 g	5×1.2 ml/ampoule	Set 2, 15 g/ampoule	8 g	10 g	10 g	30 g	5 g
Form	Frozen	Oil	Frozen	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried and micronised	Oil
Hexachloro-benzene		157.8±5.0	32.9±1.7				*1.3 (0.35–3.3)	55.7±2.0
α-HCH		85.3±3.4	16.2±3.4				*1.4 (1.3–1.5)	42±3
β-HCH			*8.0±1.4				4.6 (2.4–9.5)	16±3
γ-HCH		24.9±1.7	3.30±0.81				*11 (5.4–16)	23±4
Aldrin							*0.76 (0.5–4.5)	
trans-Chlordane	16.6±1.7	*52±7		16.6±1.8		11.38±0.56		6.9±1.6
cis-Chlordane	17.2±2.8	167.0±5.0	46.9±2.8	17.2±2.9	1.42±0.13	15.56±0.83	*1.4 (0.36–2.8)	24.4±1.8
Heptachlor							*3 (0.99–4.4)	
Heptachlor epoxide		31.6±1.5	10.8±1.3				*0.79 (0.32–1.4)	
trans-Nonachlor	18.0±3.6	214.6±7.9	231±11	18±3.6	1.43±0.10	11.5±1.0		39±4
cis-Nonachlor	6.84±0.90	94.8±2.8	48.7±7.6	6.84±0.92		8.23±0.56		
Dieldrin	*6.2±1.3	155.9±4.5	*37.5±3.9	*6.2±1.3	6.04±0.52	6.30±0.67	1.7 (0.72–2.8)	59±4
Oxychlordane		*38±4	19.8±1.9			2.13±0.27		11.0±1.8
2,4′-DDE	*5.26±0.27	22.0±1.0	12.28±0.87	*5.26±2.8		4.41±0.56		
4,4′-DDE	51.2±5.5	651±11	445±37	51.2±5.7	12.5±1.63	37.5±1.5	1.2 (0.86–1.6)	610±40
2,4′-DDD	*13.7±2.8	36.3±1.4	18.1±2.8	*13.7±2.8	3.32±0.29	10.5±1.0		30±4
4,4′-DDD	43.0±6.3	254±11	133±10	43±6.4	4.30±0.38	38.8±2.3	0.7 (0.61–0.90)	400±30
2,4′-DDT	*8.5±1.9	156.0±4.4	106±14	*8.5±1.9		9.2±1.6		
4,4′-DDT	3.91±0.59	524±12	245±15	3.91±0.60	1.28±0.18	3.84±0.28	2.2 (1.4–3.6)	179±18
Mirex		*16±3	28.9±2.8					
Endrin							*0.71 (0.43–1.6)	

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.

2. CRMs for PAHs

An overview of the available CRMs for organic contaminants in biota is given in Tables 1–5. A similar overview for organics in sediments in given in Tables 6–13. Only five materials are available for PAHs in biota: four mussel tissues of the US National Institute for Standards and Technology (NIST) and a sea plant homogenate of the IAEA (Table 1). Two mussel materials are almost similar, showing only some minor differences in their certified values due to freeze-dry losses. One material (1974a) is offered as wet, frozen material [10], the other one (2974) is freeze-dried. The wet material is, however, not shipped to Europe. The freeze-dried material is available in Europe, but is relatively expensive ($ 470 for 8 g). Two new NIST freeze-dried mussel tissue materials, SRM 2977 and 2978, are available and SRM 2977 has lower PAH values than the other three NIST mussel tissue materials. Obviously, this very limited number of PAH CRMs is insufficient to serve the market. PAHs are metabolised in fish, so there is no need for that matrix, but more shellfish CRMs are required, particularly in Europe. The analysis of PAHs in mussels is included in several international marine monitoring programmes. In addition, the analysis of PAHs in shellfish is often required during surveys following oil pollution incidents. The production of CRM PAHs in shellfish, preferably a wet material, is therefore of high priority.

Tables 6 and 7 show that there are 18 CRMs for PAHs in sediment. These include harbour sediments, estuarine sediment, and lake sediments. Remarkably, no marine sediment is included, not even from coastal waters, in spite of the fact that PAHs are regularly analysed within the framework of various marine monitoring programmes. Apparently, relatively low PAH levels as occur in marine sediments, still cause problems for the laboratories, so certification of PAHs in such materials was not possible until now. The Canadian materials EC-1 to EC-8 also have PAH values. However, generally the materials with relatively low PAH levels (below 1 mg/kg) provide only non-certified values. This situation of course also rises doubt on the quality of data obtained for PAHs in marine monitoring programmes.

The NIST 1944 sediment is the most complete CRM with 56 PAHs, most of which have been certified, and includes non-certified reference values for many alkylated PAHs.

3. CRMs for OCPs

Eight CRMs are available for OCPs in biota (Table 2). These include two cod liver oils, four mussel tissues, a whale blubber, and a sea plant homogenate. As described above, the two NIST mussel samples 1974a and 2974 are identical, one being a wet material and one being the same material, but freezed-dried (see Section 2). The other wet material is the whale blubber [11]. Unfortunately, the whale blubber cannot be sent to countries outside the USA, due to restrictions on transportation of marine mammal materials. The availability of more wet CRMs would be beneficial to the laboratories. Wet materials have the advantage of allowing the user to control his extraction step, which cannot be done with an oil and which is normally less reliable when using a freeze-dried material. In addition, wet materials have realistic concentrations which are lower than those in oils or freeze-dried materials, and are therefore better comparable with samples that are being analysed in the laboratory's routine monitoring work. Table 2 shows that most CRMs indeed have OCP concentrations that are much higher than concentrations which can normally be found in marine fish samples (ca. 0.1–2 ng/g).

Proper CRMs for OCPs in sediments are hardly available (Table 8). In fact only the NIST SRM 1944 is certified for four OCPs: HCB, *cis*-chlordane, *trans*-nonachlor and *p,p'*-DDT and SRM 1939a has only three certified values. Two new IAEA sediments, IAEA 383 and IAEA 408, have information values for a wider range of OCPs. So, for a large number of OCPs there is no sediment CRM at all. Although OCP concentrations are decreasing in many coastal waters, OCPs are still being monitored, which is also true for many freshwater locations. Consequently, CRMs for OCPs in sediments is another high priority item for CRM producers.

4. CRMs for PCBs

Twelve materials are available as CRMs for PCBs in biota (Table 3). These include two cod liver oils, a mackerel oil, five mussel tissues, a carp, a whale blubber and a sea plant homogenate. The mussels are the NIST materials 1974a, 2974, 2977 and 2978 discussed above and BCR 682. The whale blubber has also been discussed as regards its transport restrictions (see CRMs for OCPs). As for OCPs the fish oil has the disadvantage of unrealistic high levels of PCBs. In addition, the cod liver oil (BCR 349) and the mackerel oil (BCR 350) originate from 1986 and are relatively old now. As newer analytical techniques such as newer gas chromatography (GC)/mass spectrometry systems and multidimensional GC techniques were not available at the time of production, some of the certified values may be biased to some extent as some co-elution, e.g. for the CBs 101 and 138 were not observed during the certification [12,13]. The recently produced sterilised wet mussels (BCR CRM 682) are presumably of a better quality. This is the first wet, sterilised material that was produced as CRM for PCBs. It has realistic PCB concentrations which correspond with values which have to be determined by laboratories in marine monitoring programmes. The CRM is packed in tins which can easily be transported and stored at room temperature for a long time. It is also the only CRM for PCBs with a certified value for CB 138. In the other CRMs CB 138 was determined as the sum of the CBs 138 and 163 or 138, 163 and 164. The IAEA sea plant homogenate does not include more detailed information on a possible separation of these CBs, but most likely the certified value is only valid for the sum of the three CBs. Another CRM PCB in wet sterilised herring has recently been certified for 13 PCBs, including CB 138 as a single compound. This

Table 3
RMs for PCBs in biota

Code	SRM 1974a	SRM 1588a	SRM 1945	SRM 2974	SRM 2977	SRM 2978	140/OC	CARP-1	BCR 349	BCR 350	BCR 682	EDF 2524	EDF 2525
Organisation	SRM NIST	SRM NIST	SRM NIST	SRM NIST	SRM NIST	SRM NIST	IAEA	NRC[f]	BCR	BCR	BCR	CIL[g]	CIL
Country of origin	USA	USA	USA	USA	USA	USA	Monaco	Canada	EC	EC	EC	USA	USA
Matrix	Mussel tissue	Cod liver oil	Whale blubber	Mussel tissue	Mussel tissue	Mussel tissue	Fucus (sea plant homogenate)	Common carp	Cod liver oil	Mackerel oil	Mussels	Clean natural matrix (fish)	Contaminated natural matrix (fish)
Units	μg/kg	μg/kg	μg/kg	μg/kg	μg/kg	μg/kg	μg/kg	ng/kg	μg/kg	μg/kg	μg/kg	ng/kg	ng/kg
As	Dry weight	Wet weight	Wet weight	Dry weight	Dry weight	Dry weight	Dry weight	Wet weight	Wet weight	Wet weight	Wet weight	Wet weight	Wet weight
[±] expressed as	± 95% CI	± 95% CI	± 95% CI	± 95% CI	± 95% CI	± 95% CI	95% CI	± 95% CI	± 95% CI	± 95% CI	± 95% CI	95% CI	95% CI
Units of issue	3 × 15 g	5 × 1.2 ml/ampoule	Set 2, 15 g/ampoule	8 g	10 g	10 g	35 g	6 × 9 g	2 g ampoules	2 g ampoules	Tin, 70 g	Set 1, 10 g/ampoule	Set 1, 10 g/ampoule
Form	Frozen	Oil	Frozen	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried micronised	andSlurry	Oil	Oil	Wet, sterilised	Slurry	Slurry
PCB 8					2.10 ± 0.15								
PCB 16/32		*2.6 ± 0.8											
PCB 17		*6.5 ± 1.1											
PCB 18	*33 ± 11	*8.1 ± 2.2	4.48 ± 0.88	*26.8 ± 3.3	2.65 ± 0.30	*2.4 ± 0.6	*1.5 (1.2–1.9)						
PCB 22		*3.0 ± 0.6											
PCB 28	*79 ± 15	28.32 ± 0.55	*14.1 ± 1.4	*79 ± 15	5.37 ± 0.44	7.91 ± 0.90	1.7 (1.3–2.5)		68 ± 7	22.5 ± 4.0	0.30 ± 0.07		
PCB 31	*76 ± 21	8.33 ± 0.28	*3.12 ± 0.69	*76 ± 14	3.92 ± 0.24	21.40 ± 0.43	1.8 (1.7–2.1)						
PCB 33		*3.3 ± 1.4											
PCB 41/71		*5.3 ± 2.2											
PCB 42		*5.6 ± 3											
PCB 44	72.2 ± 7.4	35.1 ± 1.4	12.2 ± 1.4	72.7 ± 7.7	3.25 ± 0.63	11.80 ± 0.64	*2 (1.9–2.1)		*75	*44			
PCB 46		*11 ± 2											
PCB 49	88.8 ± 5.0	29.9 ± 0.84	20.8 ± 2.8	88.8 ± 5.7		16.84 ± 0.86	1.6 (1.1–1.9)						
PCB 52	115 ± 11	83.3 ± 2.3	43.6 ± 2.5	115 ± 12	8.37 ± 0.54	17.7 ± 2.8	3.8 (2.6–4.9)	124 ± 32	149 ± 20	62 ± 9	0.78 ± 0.09		
PCB 55/60		*18 ± 11											
PCB 64		*14 ± 1											
PCB 66	101.4 ± 4.4	54.7 ± 1.5	23.6 ± 1.6	101.4 ± 5.4	3.64 ± 0.32	18.4 ± 1.5	*0.89 (0.65–1.10)						
PCB 70							*1.8 (1.1–4.0)						
PCB 70/76		*27 ± 4											
PCB 74		*40 ± 4											
PCB 83		*21 ± 5											
PCB 85		*27 ± 8											
PCB 87	*54 ± 14	56.3 ± 1.1 *21 ± 8	16.7 ± 1.4	*54 ± 14	2.15 ± 0.10	10.20 ± 0.29	*1.6 (1.2–2.0)						
PCB 95	83 ± 17	36.5 ± 1.1	33.8 ± 1.7	83 ± 17	5.39 ± 0.59	20.8 ± 2.1							
PCB 97		*42 ± 4											
PCB 99	70.9 ± 4.0		45.4 ± 5.4	70.9 ± 4.5	1.59 ± 0.20	18.84 ± 0.44	*0.9 (0.75–1.4)						
PCB 101	128.3 ± 9.7	126.5 ± 4.3		128 ± 10			2.4 (1.9–3.2)		170 ± 17	163 ± 9			
PCB 101/90			65.2 ± 5.6		11.2 ± 1.2	35.9 ± 1.6		124 ± 37					
PCB 105	53.0 ± 3.4	60.2 ± 2.3	30.1 ± 2.3	53 ± 3.8	3.76 ± 0.49	10.85 ± 0.45	0.49 (0.4–0.7)	54 ± 24			*0.50 ± 0.07	323 ± 90	43 697 ± 4 912
PCB 110	127.3 ± 8.6	76.0 ± 2.0	23.3 ± 4.0	127.3 ± 9.4	4.03 ± 0.20	35.34 ± 0.71							
PCB 118	130.8 ± 3.6	176.3 ± 3.8	74.6 ± 5.1	130.8 ± 5.3	10.5 ± 1.0	35.1 ± 1.0	1 (0.97–1.1)	132 ± 60	456 ± 31	143 ± 20	2.6 ± 0.3	691 ± 170	76 803 ± 24 096
PCB 128	22.0 ± 3.4	47.0 ± 2.4	23.7 ± 1.7	22 ± 3.5	2.49 ± 0.28	5.25 ± 0.17			*104	*41			

Table 3 (*continued*)

Code	SRM 1974a	SRM 1588a	SRM 1945	SRM 2974	SRM 2977	SRM 2978	140/OC	CARP-1	BCR 349	BCR 350	BCR 682	EDF 2524	EDF 2525
PCB 136		*14 ± 2											
PCB 137		*16 ± 2											
PCB 138							1.7 (1.2-2.6)				4.6 ± 0.8		
PCB 138/163									*765	*274			
PCB 138/163/164	133.5 ± 9.5	263.5 ± 9.1	131.5 ± 7.4	134 ± 10	16.6 ± 1.6	35.7 ± 1.5		102 ± 23					
PCB 141		*24 ± 4											
PCB 146		*39 ± 6											
PCB 149	87.6 ± 2.3	105.7 ± 3.6	106.6 ± 8.4	87.6 ± 3.5	9.23 ± 0.12	34.73 ± 0.69	1.2 (1.1-1.6)				5.7 ± 0.6		
PCB 151	25.6 ± 3.5	54.8 ± 2.1	28.7 ± 5.2	25.6 ± 3.6	3.07 ± 0.18	10.92 ± 0.25							
PCB 153	145.2 ± 7.6	273.8 ± 7.7	213 ± 13	145.2 ± 8.8	14.1 ± 1.0	56.9 ± 3.5	1.7 (1.3-3.1)	83 ± 39	938 ± 40	317 ± 20	9.2 ± 0.8		
PCB 156	7.43 ± 0.99	27.3 ± 1.8	10.3 ± 1.1	7.4 ± 1.0	0.960 ± 0.085	1.97 ± 0.11	0.17 (0.08-0.36)						
PCB 158		*21 ± 2											
PCB 170	5.5 ± 1.1	46.5 ± 1.1		5.5 ± 1.1	2.95 ± 0.23	*7 ± 2	*0.21 (0.16-0.76)				0.17 ± 0.05		
PCB 170/190			40.6 ± 2.6					22 ± 8					
PCB 180	17.1 ± 3.8	105.0 ± 5.2	106.7 ± 5.3	17.1 ± 3.8	6.79 ± 0.67	7.81 ± 0.63	0.43 (0.38-0.52)	46 ± 14	280 ± 22	73 ± 13	0.77 ± 0.07		
PCB 172/197		*17 ± 4											
PCB 174		*41 ± 10											
PCB 177		*4.8 ± 0.8											
PCB 178/129		*29 ± 1											
PCB 179		*4.4 ± 1.2											
PCB 183	16.0 ± 2.4	31.21 ± 0.62	36.6 ± 4.1	16.0 ± 2.4	1.33 ± 0.10	5.25 ± 0.15							
PCB 187			105.1 ± 9.1				*0.38 (0.30-1.2)						
PCB 187/182								36 ± 16					
PCB 187/159/182	34.0 ± 2.3	35.23 ± 0.83		34.0 ± 2.5	4.76 ± 0.38	16.7 ± 1.3							
PCB 189		*2.9 ± 0.6											
PCB 191		*4.5 ± 0.7											
PCB 193		*14 ± 3											
PCB 194		15.37 ± 0.61	39.6 ± 2.5		0.897 ± 0.042				*38				
PCB 195		*4.6 ± 0.6	17.7 ± 4.3										
PCB 196/23		*24 ± 3											
PCB 199		*17 ± 2											
PCB 201		12.18 ± 0.46	16.96 ± 0.89										
PCB 206		*3.4 ± 1.6	31.1 ± 2.7										
PCB 209		*3.5 ± 1.0	10.6 ± 1.1										

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.

Table 4
RMs for chlorinated dioxins, furans and non-ortho PCBs in biota

Code	SRM 1588a	CARP-1	EDF 2524	EDF 2525	EDF 2526	140/OC
Organisation	SRM NIST	NRC	CIL[2]	CIL	CIL	IAEA
Country of origin	USA	Canada	USA	USA	USA	Monaco
Matrix	Cod liver oil	Common carp	Clean natural matrix (fish)	Contaminated natural matrix (fish)	Fortified fish	Fucus (sea plant homogenate)
Units	µg/kg	ng/kg	ng/kg	ng/kg	ng/kg	µg/kg
As	Wet weight	Wet weight	Wet weight	Wet weight	Wet weight	Dry weight
[±] expressed as	±95% CI	±95% CI	95% CI	95% CI	95% CI	95% CI
Units of issue	5×1.2 ml/ampoule	6×9 g	Set 1, 10 g/ampoule	Set 1, 10 g/ampoule	Set 1, 10 g/ampoule	30 g
Form	Oil	Slurry	Slurry	Slurry	Slurry	Freeze-dried and micronised
2,3,7,8-TCDF		11.9±2.7	2.5±0.16	22±1.6	17±1.5 (25)[b]	
1,2,3,7,8-PCDF		5.0±2.0	ND[a]	4.9±0.56	40±3.7 (50)	
2,3,4,7,8-PCDF			ND	14±1.3	38±3.5 (50)	
1,2,3,4,7,8-HxCDF			ND	8.2±3.7	80±8.4 (75)	
1,2,3,6,7,8-HxCDF			ND	2.7±1.2	63±5.5 (75)	
1,2,3,7,8,9-HxCDF			ND	0.76±0.35	58±7.0 (75)	
2,3,4,6,7,8-HxCDF			ND	2.3±1.9	60±5.5 (75)	
1,2,3,4,6,7,8-HpCDF			ND	4.4±6.0	83±9.2 (100)	
1,2,3,4,7,8,9-HpCDF			ND	0.63±0.23	73±7.7 (100)	
OCDF	*1.00		ND	2.6±1.3	190±22 (100)	
1,2,7-TriCDD	*0.32					
1,2,3,4-TCDD	*0.38					
2,3,7,8-TCDD	*0.21	6.6±0.6	ND	17±1.4	19±1.4 (25)	
1,2,3,7,8-PCDD		4.4±1.1	ND	4.0±0.57	40±3.0 (50)	
1,2,3,4,7,8-HxCDD		1.9±0.7	ND	0.77±0.27	60±4.8 (75)	
1,2,3,6,7,8-HxCDD	*0.39	5.6±1.3	ND	3.0±1.2	56±4.8 (75)	
1,2,3,7,8,9-HxCDD	*0.22	0.7±0.4	ND	0.79±0.26	60±4.4 (75)	
1,2,3,4,6,7,8-HpCDD		6.5±1.8	ND	1.4±0.53	76±5.9 (100)	
OCDD	*1.01	6.3±1.9	ND	7.2±3.7	192±14 (350)	
PCB 77			13.8±7.0	1945±354	619±107 (600)	*0.19 (0.04–6.9)
PCB 126			3.9±1.8	647±148	1140±465 (600)	
PCB 169			1.8±2.3	50±12	1416±553 (600)	

Values preceded by an asterisk (*) are non-certified; all other values are certified.
[a]ND – not detected.
[b]Figure in brackets represents the amount of each analyte added to the matrix.

Table 5
RMs for organotin compounds in biota

Antifouling	BCR 477	NIES 11
Country of origin	EU	Japan
Matrix	Mussel tissue	Fish tissue
Units	mg/kg	mg/kg
As	Dry weight	Dry weight
[±] expressed as	1/2-width of 95% CI of mean	2×S.D.
Units of issue	14 g	20 g
Form	Dried	Freeze-dried
Triphenyltin (as chloride)		*6.3
TBT	2.2±0.19	1.3±0.1
DBT	1.54±0.12	
MBT	1.50±0.28	

Values preceded by an asterisk (*) are non-certified; all other values are certified.

material (BCR CRM 718) is waiting for the last stability tests and is expected to become available in 2001. The advantage of the NIST materials is that they give certified values for a broad range of PCB congeners, whereas the BCR materials and the carp CRM of the National Research Council (NRC, Canada) have only certified values for a limited number of PCBs, although those PCBs are the ones which are being analysed for monitoring purposes. In particular, the cod liver oil, NIST SRM 1588a, contains a large suite of certified and reference values for PCBs. Recently, NIST has certified a new CRM, coded SRM 1946 [14]. This CRM has been certified for fatty acids but includes certified values for 10 PCBs and three OCPs.

There are 18 RMs for PCBs in sediment, of which eight contain certified values. Some of them (NRC CS-1, NWRI EC-1 and EC-2) have only been certified for total PCB (Tables 9 and 10). The list includes harbour sediments, estuarine sediments and lake sediments. As for OCPs, no marine sediment is available, whereas PCBs are frequently monitored in marine monitoring programmes such as the Joint Monitoring and Assessment Programme (JAMP) of the Oslo and Paris Commissions. The SRM 1944 offers the most complete set of certified values, including 35 PCBs (some in combination). Wet sediments have not been produced until now. Recently, wet sediments have successfully been used in interlaboratory studies within the QUASIMEME programme [15]. This shows that in principle the technology for producing wet sediment CRMs is available. Wet sediment CRMs for PCBs would be a useful addition to the current list.

5. CRMs for PCDDs, PCDFs and dioxin-like PCBs

There are six CRMs for PCDDs, PCDFs and dioxin-like PCBs in biota: a cod liver oil, a carp, three unidentified fish samples of which one has been spiked, and a sea plant homogenate (Table 4). The NIST 1588a cod liver oil has only indicative values for these contaminants, whereas the carp CRM CARP-1 only has certified values for a limited number of PCDDs. The two fish CRMs produced by Cambridge Isotope Laboratories comprise a rather complete set of PCDDs, PCDFs and dioxin-like PCBs. The uncertainty ranges are, however, relatively large for the unspiked material (ca. 30–140% for some PCDDs and PCDFs and PCB 169) and EDF 2524 mostly has values given as non-detected. A candidate CRM for non-ortho PCBs (77, 81, 126 and 169) in chub has been prepared for BCR. This material is currently being certified and, in case that will be successful, it will become available in 2002. Obviously, also here is a clear need for more CRMs. Particularly since the Belgian dioxin crisis in 1999 [16], discussions on new maximum residue limits for PCDDs, PCDFs and dioxin-like PCBs are taking place at national levels and in the European Union [17,18]. From these discussions it becomes clear that the highest risks can be found in fish and in animal feed based on fish products, particularly because the dioxin-like PCBs have relatively high contribution to the total TCCD equivalent. Although this rather serves the food control laboratories than environmental laboratories, it is clear that there is a need for CRMs for PCDDs, PCDFs and dioxin-like PCBs in fish, next to such CRMs for other food stuffs and animal feed. Such CRMs for fish should include certified values for all PCDDs, PCDFs and dioxin-like PCBs which have been given a TCDD equivalency factor by the World Health Organisation (WHO) [19]. Given the possible relatively strict maximum residue limits which may be proposed, such CRMs are of high priority.

Table 11 shows that there are seven sediment CRMs for PCDDs, PCDFs and dioxin-like PCBs. Unfortunately, the EC-1 to EC-3 sediments only contain indicative values for the three non-ortho PCBs, whereas the other five sediments only have indicative (NIST SRM 1944, NWRI DX-3) or certified values (NWRI DX-1 and DX-2) for the PCDDs and PCDFs. The CIL material has been fortified. A preferably unspiked sediment CRM in which both dioxin-like PCBs and PCDDs and PCDFs would be certified would be most welcome.

6. CRMs for chlorinated benzenes

There are no CRMs for chlorinated benzenes in biota. Only HCB is certified in a number of OCP CRMs (Table 2). Table 12 shows eight CRMs which all have predominantly indicative values for chlorinated benzenes, hexachlorobutadiene, and octachlorostyrene in sediments. These materials, EC-1 to EC-8, were all made available by the National Water Research Institute (NWRI), Canada. No European CRMs are available for chlorinated benzenes in biota. HCB is certified in three sedi-

Table 6
RMs for hydrocarbons in sediments

Code	SES-1	HS-3B	HS-4B	HS-5	HS-6	SRM 1944[a]	IAEA 383	IAEA 408	BCR 535	LGC 6188
Organisation	NRC-CNRC	NRC-CNRC	NRC-CNRC	NRC-CNRC	NRC-CNRC	SRM NIST	IAEA	IAEA	BCR	LGC
Country of origin	Canada	Canada	Canada	Canada	Canada	USA	Monaco	Monaco	EU	UK
Matrix	Estuarine sediment	Harbour sediment	Harbour sediment	Harbour sediment	Harbour sediment	New York, New Jersey, Waterway sediment	Sediment (Tagus Estuary mudflats)	Sediment (Venice Lagoon)	Freshwater harbour sediment	River sediment
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	μg/kg	μg/kg	mg/kg	mg/kg
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as		90% CI	90% CI	90% CI	90% CI	95% CI	95% CI	95% CI	1/2-width of 95% CI of mean	1/2-width of 95% CI
Units of issue	100 g	100 g	100 g	100 g	100 g	50 g	35 g	40 g	40 g	30 g
Form	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried, <250 μm	Freeze-dried, <150 μm	Dried	Air-dried
Acenaphthene	*7.21	1.25±0.02	0.09 ± 0.02	0.23 ± 0.10	0.23 ± 0.07	*0.57 ± 0.03	16 (13–21)	*3.3 (2.0–17)		*0.07 ± 0.02
Acenaphthylene		0.6 ± 0.10	0.3 ± 0.10	<0.15	0.19 ± 0.05		47 (31–59)	*3.6 (2.1–4.7)		*0.1
Anthracene	*1.63	2.76 ± 0.06	0.46 ± 0.06	0.38 ± 0.15	1.1 ± 0.4	1.77 ± 0.33	30 (25–34)	9.8 (8.0–13)		*0.36 ± 0.11
Anthranene						*0.9 ± 0.1				
Benzo[a]anthracene	*1.31	7.91 ± 0.09	1.46 ± 0.09	2.9 ± 1.2	1.8 ± 0.3	4.72 ± 0.11	105 (83–130)	53 (35–60)	1.54 ± 0.10	*0.83 ± 0.18
Benzo[b]chrysene						0.63 ± 0.10				
Benzo[a]fluoranthene						0.78 ± 0.12				
Benzo[b]fluoranthene				2.0 ± 0.15	2.8 ± 0.6	3.87 ± 0.42	150 (96–190)	46 (32–69)	2.29 ± 0.15	*0.82 ± 0.19
Benzo[k]fluoranthene				1.0 ± 0.4	1.43 ± 0.15	2.30 ± 0.20	73 (48–76)	46 (26–61)	1.09 ± 0.15	*0.50 ± 0.08
Benzo[b,k]fluoranthene (combined value)		12.8 ± 0.12	3.32 ± 0.12							
Benzo[j]fluoranthene						2.09 ± 0.44				
Benzo[a]pyrene	*1.21	5.80 ± 0.15	1.55 ± 0.15	1.7 ± 0.8	2.2 ± 0.4	4.30 ± 0.13	120 (77–140)	48 (30–63)	1.16 ± 0.10	*0.65 ± 0.14
Benzo[e]pyrene						3.28 ± 0.11	160 (120–210)	55 (51–81)	1.86 ± 0.13	
Benzo[ghi]perylene	*1.21	3.88±0.15	1.23 ± 0.15	1.3 ± 0.3	1.78 ± 0.72	2.84 ± 0.10	190 (69–230)	38 (20–52)		*0.36 ± 0.13
Biphenyl		0.41 ± 0.02	0.04 ± 0.002			*0.32 ± 0.07	*29 (19–30)			
Chrysene/triphenylene										
Chrysene	*1.32	8.77 ± 0.11	1.76 ± 0.11	2.8 ± 0.9	2.0 ± 0.3	4.86 ± 0.10	170 (120–220)	35 (25–56)		*0.83 ± 0.16
Coronene		0.83 ± 0.04	0.31 ± 0.04							
Dibenz[a,h]anthracene	*1.30	0.89 ± 0.04	0.34 ± 0.04	0.2 ± 0.1	0.49 ± 0.16	0.424 ± 0.069	*20 (18–41)	*11 (7.8–14)		*0.13 ± 0.05
Dibenz[a,c]anthracene						0.335 ± 0.013				
Dibenz[a,j]anthracene						0.50 ± 0.044				
Dibenz[a,i]pyrene		0.59 ± 0.03	0.16 ± 0.03							
Dibenzofuran		2.2 ± 0.02	0.14 ± 0.02							
Dibenzothiophene		1.19 ± 0.02	0.11 ± 0.02			*0.62 ± 0.01				
2,6-Dimethylnaphthalene							*13 (7.1–23)			
Fluoranthene	*1.58	25.33 ± 0.11	3.33 ± 0.11	8.4 ± 2.6	3.54 ± 0.65	8.92 ± 0.32	290 (260–350)	84 (53–110)		*1.79 ± 0.35
Fluorene	*1.42	2.38 ± 0.04	0.16 ± 0.04	0.4 ± 0.1	0.47 ± 0.12	*0.85 ± 0.03	27 (24–34)	*6.7 (4.6–24)		*0.12 ± 0.04
Indeno[1,2,3-cd]pyrene	*1.28			1.3 ± 0.7	1.95 ± 0.58	2.78 ± 0.10	*150 (130–160)	*51 (45–53)	1.56 ± 0.14	*0.37 ± 0.14

Table 6 (*continued*)

Code	SES-1	HS-3B	HS-4B	HS-5	HS-6	SRM 1944[a]	IAEA 383	IAEA 408	BCR 535	LGC 6188
1-Methylnaphthalene		0.73 ± 0.02	0.16 ± 0.02			*0.52 ± 0.08	14 (11–28)	*7.5 (4.7–12)		
2-Methylnaphthalene						*0.95 ± 0.05	*36 (26–43)	*14 (13–33)		
1-Methylphenanthrene						*1.7 ± 0.1	24 (18–28)	*10 (9.2–11)		
2-Methylphenanthrene						*1.90 ± 0.60	31 (24–38)	*12 (12–14)		
3-Methylphenanthrene						*2.1 ± 0.1				
4-Methylphenanthrene / 9-methylphenanthrene						*1.6 ± 0.2				
Naphthalene	*3.62	2.14 ± 0.02	0.22 ± 0.02	0.25 ± 0.07	4.1 ± 1.1	1.65 ± 0.31	96 (52–110)	27 (16–47)		*0.22 ± 0.11
Perylene						1.17 ± 0.24	58 (41–130)	320 (140–420)		
Phenanthrene	*1.37	18.8 ± 0.08	1.91 ± 0.08	5.2 ± 1.0	3.0 ± 0.6	5.27 ± 0.22	160 (140–190)	35 (21–43)		*1.04 ± 0.30
Pyrene	*4.09	18 ± 0.10	2.55 ± 0.10	5.8 ± 1.8	3.0 ± 0.6	9.70 ± 0.42	280 (210–350)	77 (57–93)	2.52 ± 0.18	*1.48 ± 0.50
Picene						0.518 ± 0.093				
Triphenylene						1.04 ± 0.27				
Benzo[c]phenanthrene						0.76 ± 0.10				
Pentaphene						0.288 ± 0.026				
n-C17							380 (330–470)	74 (56–140)		
n-C18							*83 (42–230)	*90 (60–110)		
Pristane							*87 (36–240)	69 (50–130)		
Phytane							*57 (43–150)	78 (63–130)		
Resolved aliphatics							*9 600 (6 700–24 000)	11 000 (6 400–17 000)		
Unresolved aliphatics							*52 000 (11 000–79 000)	*110 000 (68 000–150 000)		
Total aliphatics							*52 000 (14 000–85 000)	*120 000 (81 000–160 000)		
Sum alkanes (C14–C34)							*6 100 (5 300–6 800)	8 100 (4 300–12 000)		
Total aromatics							*8 800 (1 500–22 000)	*3 700 (1 300–11 000)		
Resolved aromatics							*2 500 (400–6 000)	*1 900 (240–6 800)		
Unresolved aromatics							*6 600 (1 100–16 000)			
UVF chrysene							*13 000 (1 800–28 000)	*6 000 (4 600–19 000)		
UVF ROPME oil							*96 000 (12 000–225 000)	*49 000 (35 000–120 000)		

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.

[a]Reference values are also available for dimethylphenanthrenes, methylfluoranthenes and methylpyrenes for SRM 1944.

Table 7
RMs for hydrocarbons in sediments

Code	EC-1	EC-2	EC-3	EC-4	EC-5	EC-6	EC-7	EC-8
Organisation	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI
Country of origin	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Matrix	Freshwater harbour sediment	Lake Ontario sediment	Lake Ontario sediment	Freshwater harbour sediment	River sediment	Lake Erie sediment	Lake St. Clair sediment	Lake Ontario sediment
Units	μg/g	μg/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.
Units of issue	100 g	100 g	100 g	100 g	100 g	100 g	100 g	100 g
Form	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried
Acenaphthene		*0.20 ± 0.04	*22 ± 9	*32 ± 9	*29 ± 9	*7 ± 2	*3 ± 1	*13 ± 3
Acenaphthylene		*0.12 ± 0.02	*25 ± 8	*48 ± 12	*41 ± 9	*12 ± 4	*13 ± 7	*28 ± 4
Anthracene	1.2 ± 0.3	*0.11 ± 0.02	*59 ± 11	*124 ± 16	*113 ± 17	*37 ± 5	*22 ± 5	*41 ± 6
Benzo[a]anthracene	8.7 ± 0.8	1.42 ± 0.25	312 ± 28	*712 ± 117	*503 ± 47	184 ± 27	*110 ± 22	*168 ± 18
Benzo[b]fluoranthene	7.9 ± 0.9	2.48 ± 0.043	*505 ± 88	*753 ± 148	*480 ± 88	267 ± 90	*90 ± 32	*208 ± 24
Benzo[k]fluoranthene Benzo[j]fluoranthene	4.4 ± 0.5	1.93 ± 0.36	*271 ± 104	*560 ± 562	*419 ± 49	*159 ± 50	*84 ± 2	*294 ± 37
Benzo[a]pyrene	5.3 ± 0.7	1.21 ± 0.28	386 ± 50	*675 ± 114	*449 ± 61	*250 ± 76	*103 ± 48	*207 ± 26
Benzo[e]pyrene	5.3 ± 0.6	1.91 ± 0.36	450 ± 49	*747 ± 93	*440 ± 76			*531 ± 177
Benzo[ghi]perylene	4.9 ± 0.7	1.47 ± 0.33	*348 ± 70	*576 ± 122	*333 ± 53	*176 ± 43	*95 ± 8	*176 ± 32
Chrysene/triphenylene	*9.2 ± 0.9	*2.15 ± 0.86	*458 ± 59	*1073 ± 150	*619 ± 60	*279 ± 29	*182 ± 51	*378 ± 38
Dibenz[a,h]anthracene	*1.3 ± 0.2	0.49 ± 0.10	*109 ± 17	*241 ± 96	*195 ± 44	*42 ± 9	*34 ± 6	*316 ± 79
Fluoranthene	23.2 ± 2.0	3.55 ± 0.41	558 ± 46	*1087 ± 139	*823 ± 74	*297 ± 48	*196 ± 32	*462 ± 41
Fluorene		*2.14 ± 0.40	*42 ± 21	*88 ± 35	*84 ± 26	*17 ± 3	*16 ± 4	*19 ± 2
Indeno[1,2,3-cd]pyrene	5.7 ± 0.6	1.55 ± 0.26	*359 ± 36	*564 ± 101	*386 ± 66	*157 ± 53	*62 ± 14	*34 ± 6
Naphthalene		*1.47 ± 1.05	*35 ± 20	*58 ± 14	*26 ± 6	*75 ± 12	*40 ± 9	*10 ± 1
Perylene	*1.1 ± 0.2	*0.80 ± 0.26	*195 ± 21	*280 ± 93	*187 ± 28	*0.075	*0.040	*202 ± 25
Phenanthrene	15.8 ± 1.2	*1.41 ± 0.16	293 ± 33	*732 ± 75	*612 ± 57	*138 ± 12	*180 ± 17	*234 ± 19
Pyrene	16.7 ± 2.0	2.92 ± 0.31	436 ± 47	*1085 ± 170	*987 ± 134	*337 ± 48	*306 ± 58	*327 ± 30

Values preceded by an asterisk (*) are non-certified; all other values are certified.

ment CRMs (NIST 1944, NWRI EC-2 and EC-3) for OCPs (Tables 8 and 12). The degree of difficulty of this type of analysis may be one of the reasons for the lack of good CRMs. Obviously, there is a need for more CRMs for chlorinated benzenes and octachlorostyrene in biota and sediments.

7. CRMs for organotin compounds

Two CRMs are available for antifouling compounds: BCR 477, showing certified values for tri-, di- and monobutyltin (TBT, DBT and MBT) and the Japanese material NIES 11 showing a certified value for TBT and an indicative value for triphenyltin (Table 5). Given the concern about environmental levels of TBT in marine organisms, the production of more CRMs seems to be justified. Table 13 shows one CRM for antifouling compounds in sediment: BCR 462, which is a coastal sediment and has certified values for TBT and for DBT. Although, admittedly, only a few specialised laboratories study organotin compounds in sediments, tone CRM is a very small basis, even to serve this limited number of laboratories.

8. Conclusions

Although a number of good quality CRMs have been produced over the last two decades, there is still a need for a number of good CRMs to serve

Table 8
RMs for chlorinated pesticides in sediments

Code	SRM 1944	SRM 1939a	IAEA 383	IAEA 408
Organisation	SRM NIST	SRM NIST	IAEA	IAEA
Country of origin	USA	USA	Monaco	Monaco
Matrix	New York, New Jersey, Waterway sediment	River sediment	Sediment (Tagus Estuary mudflats)	Sediment (Venice Lagoon)
Units	mg/kg	µg/kg	µg/kg	µg/kg
As	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	95% CI	95% CI	95% CI	95% CI
Units of issue	50 g	50 g	35 g	40 g
Form	Freeze-dried	Air-dried	Freeze-dried, < 250 µm	Freeze-dried, < 150 µm
Hexachlorobenzene	6.03 ± 0.35		*38 (17–57)	0.41 (0.30–0.57)
α-HCH	*2.0 ± 0.3		*0.29 (0.13–3.7)	*0.61 (0.21–1.5)
β-HCH			*0.57 (0.26–9.7)	*0.55 (0.38–1.7)
γ-HCH			*0.46 (0.16–1.1)	0.19 (0.11–0.20)
Aldrin			*1.4 (0.84–5.9)	*0.41 (0.2–0.23)
trans-Chlordane	*8 ± 2		*1.4 (0.8–1.9)	*0.27 (0.06–0.48)
cis-Chlordane	16.51 ± 0.83	4.8 ± 1.3	*0.47 (0.06–0.73)	*0.12 (0.10–0.34)
Heptachlor			*1 (0.51–2.5)	*0.42 (0.23–0.70)
Heptachlor epoxide			*1.5 (0.42–5.9)	*0.64 (0.43–1.5)
trans-Nonachlor	8.20 ± 0.51			
cis-Nonachlor	*3.7 ± 0.7			
Dieldrin			*0.27 (0.1–0.57)	*0.3 (0.30–0.48)
2,4′-DDE	*1.9 ± 3		*0.21 (0.062–0.73)	
4,4′-DDE	*86 ± 12		1.2 (0.75–1.8)	1.4 (0.88–2.0)
2,4′-DDD	*38 ± 8		*1.2 (0.54–2.5)	*0.19 (0.18–0.33)
4,4′-DDD	*108 ± 16	5.50 ± 0.97	*1.8 (0.8–3.6)	*0.87 (0.56–1.7)
2,4′-DDT			*0.39 (0.067–0.82)	*0.38 (0.09–3.8)
4,4′-DDT	119 ± 11	2.72 ± 0.42	*2.4 (0.86–6.1)	0.67 (0.48–0.98)
Endrin			*1.1 (0.4–1.8)	*0.57 (0.14–1.2)
α-Endosulfan			*0.31 (0.15–0.57)	*1.6 (0.3–6.2)
Endosulfan sulfate			*1.7 (0.92–7.1)	*1.6 (0.5–8.2)

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.
Note: NWRI EC1-8 contain certified and reference chlorobenzene values in sediments and include hexachlorobenzene HCB. These results are presented in Table 12.

laboratories working in the field of organic contaminant analysis in the aquatic environment. In order of priority, there is a need for CRMs for PCDDs, PCDFs and non- and mono-ortho PCBs having WHO TEF values in biota and sediments, PAHs in shellfish, OCPs in wet biota and sediment, PCBs in wet sediment, chlorinated benzenes in biota and sediment and organotin compounds in biota and sediment. In addition, the production of CRMs for new contaminants such as brominated flame retardants should be considered. As regards the available CRMs, laboratories should critically evaluate the process of their production and certification, prior to using them, as there is a wide range in quality. Also, suppliers of CRMs should inform the users on how to use the available CRMs [20]. A definition of minimum requirements for the production of CRMs and registration and accreditation of producers, which would help the user to distinguish CRMs from RMs, is highly recommended.

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Table 9
RMs for PCBs in sediment

Code	CS-1	HS-1	HS-2	SRM 1944	SRM 1939a	IAEA 383	IAEA 408	BCR 536	LGC 6114
Organisation	NRC-CNRC	NRC-CNRC	NRC-CNRC	SRM NIST	SRM NIST	IAEA	IAEA	BCR	LGC
Country of origin	Canada	Canada	Canada	USA	USA	Monaco	Monaco	EU	UK
Matrix	Harbour sediment	Harbour sediment	Harbour sediment	New York, New Jersey, Waterway sediment	River sediment	Sediment (Tagus Estuary mudflats)	Sediment (Venice Lagoon)	Freshwater harbour sediment	Naval Dockyard harbour sediment
Units	µg/kg	µg/kg	µg/kg	mg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	± S.D.	± S.D.	± S.D.	95% CI	95% CI	95% CI	95% CI	1/2-width of 95% CI	1/2-width of 95% CI
Units of issue	100 g	100 g	100 g	50 g	50 g	35 g	40 g	40 g	50 g
Form	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Air-dried	Freeze-dried, < 250 µm	Freeze-dried, < 150 µm	Dried	Air-dried, < 150 µm
PCB 8				22.3 ± 2.3			*0.24 (0.22–4.6)		
PCB 18				51.0 ± 2.6	*3210 ± 940	*0.5 (0.27–0.78)	*0.74 (0.13–1.9)		
PCB 28				80.8 ± 2.7	*2461 ± 78	1 (0.77–1.4)	0.79 (0.35–0.98)	44 ± 5	*15 ± 8
PCB 31				78.7 ± 1.6	*6440 ± 490	0.76 (0.38–1.2)	*0.43 (0.09–1.5)		
PCB 44				60.2 ± 2.0	1131 ± 74	*1.1 (0.92–1.2)	*0.47 (0.23–3.0)		
PCB 49				53.0 ± 1.7	3740 ± 280	*1.1 (0.89–1.3)	*0.35 (0.22–0.38)		
PCB 52				79.4 ± 2.0	4320 ± 130	2.5 (1.1–2.8)	0.6 (0.38–0.93)	38 ± 4	*337 ± 57
PCB 66				71.9 ± 4.3	840 ± 130	*2 (1.8–3.1)			
PCB 87				29.9 ± 4.3		*0.7 (0.55–0.91)	*0.87 (0.26–1.1)		
PCB 95				65.0 ± 8.9	*1210 ± 420	*3.6 (2.7–4.5)			
PCB 97						*0.41 (0.26–0.9)			
PCB 99				37.5 ± 2.4	380 ± 96	*1.3 (0.59–1.8)			
PCB 101/90				73.4 ± 2.5					
PCB 101		1.62 ± 0.21	5.42 ± 0.34			2.9 (1.3–4.2)	1.2 (0.81–1.7)	44 ± 4	*810 ± 193
PCB 105				24.5 ± 1.1	201 ± 28	0.99 (0.77–1.5)	0.57 (0.44–0.67)	3.5 ± 0.6	
PCB 110				63.5 ± 4.7	1068 ± 70	2.4 (1.8–3.6)	0.83 (0.50–0.90)		
PCB 118				58.0 ± 4.3	423 ± 88	3.3 (2.2–4.1)	1.2 (0.9–1.6)	28 ± 3	*688 ± 200
PCB 128				8.47 ± 0.28	91.2 ± 8.4	0.63 (0.52–0.87)	0.33 (0.27–0.53)	5.4 ± 1.2	
PCB 137						*0.17 (0.09–0.22)			
PCB 138		1.98 ± 0.28	6.92 ± 0.52			4.4 (2.6–6.1)	1.6 (1.1–2.1)	27 ± 4	*649 ± 164
PCB 138/163/164				62.1 ± 3.0	258.1 ± 6.9				
PCB 141						*0.64 (0.34–1.1)			
PCB 149				49.7 ± 1.2	427 ± 47	3.2 (2.3–3.7)	1.4 (1.3–1.6)	49 ± 4	
PCB 151		0.48 ± 0.08	1.37 ± 0.07	16.93 ± 0.36	192.1 ± 2.6	*0.58 (0.37–1.1)			
PCB 153		2.27 ± 0.28	6.15 ± 0.67	74.0 ± 2.9	297 ± 19	4.3 (2.3–5.4)	1.9 (0.98–2.1)	50 ± 4	*537 ± 127
PCB 156				6.52 ± 0.66	37.0 ± 6.6	*0.47 (0.24–0.78)	*0.36 (0.31–0.39)	3.0 ± 0.4	
PCB 158						*0.39 (0.18–0.57)			
PCB 163								17 ± 3	

(Continued on next page)

Table 9 (*continued*)

Code	CS-1	HS-1	HS-2	SRM 1944	SRM 1939a	IAEA 383	IAEA 408	BCR 536	LGC 6114
PCB 170		0.27 ± 0.05	1.07 ± 0.15		107 ± 17	0.82 (0.62–1.3)	0.47 (0.34–0.59)	13.4 ± 1.4	
PCB 170/190				22.6 ± 1.4					
PCB 174						*0.67 (0.42–0.92)	*0.34 (0.20–0.44)		
PCB 177						*0.56 (0.35–0.73)	*0.35 (0.23–0.43)		
PCB 180		1.17 ± 0.15	3.70 ± 0.33	44.3 ± 1.2	140.3 ± 6.1	2.5 (1.9–3.4)	1.1 (0.85–1.2)	22 ± 2	*119 ± 22
PCB 183				12.19 ± 0.57	47.3 ± 2.3	0.47 (0.34–0.57)	*0.32 (0.26–0.33)		
PCB 185						*1.3 (0.073–0.18)			
PCB 187						1.3 (0.63–1.5)	0.68 (0.49–0.94)		
PCB 187/159/182				25.1 ± 1.0	156.4 ± 2.6				
PCB 189						*0.07 (0.041–1.4)			
PCB 194		0.23 ± 0.04	0.61 ± 0.07	11.2 ± 1.4	35.5 ± 4.1	0.54 (0.31–0.73)	0.2 (0.2–0.23)		
PCB 195				3.75 ± 0.39		*0.24 (0.13–0.29)	*0.12 (0.06–0.16)		
PCB 196		0.45 ± 0.04	1.13 ± 0.12				*0.22 (0.17–0.40)		
PCB 199						*0.091 (0.01–0.35)			
PCB 200						*0.16 (0.051–0.22)			
PCB 201		0.57 ± 0.07	1.39 ± 0.09			*0.71 (0.28–0.74)			
PCB 205						*0.033 (0.027–0.050)			
PCB 206				9.21 ± 0.51	29.7 ± 5.6	*0.48 (0.44–1.1)			
PCB 207						*0.094 (0.05–0.19)			
PCB 209		0.33 ± 0.1	0.90 ± 0.14	6.81 ± 0.33		2.1 (1.2–3.0)			
Total PCB	1.2 ± 0.60	21.8 ± 1.1	111.8 ± 2.5						

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.
LGC values for PCBs are classified as 'assessed' values.

Table 10
RMs for PCBs in sediments

Code	EC-1	EC-2	EC-3	EC-4	EC-5	EC-6	EC-7	EC-8[b]	DX-3[a]
Organisation	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI
Country of origin	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Matrix	Freshwater harbour sediment	Lake Ontario sediment	Lake Ontario sediment	Freshwater harbour sediment	River sediment	Lake Erie sediment	Lake St. Clair sediment	Lake Ontario sediment	Great Lakes sediment
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	± S.D.	+ S.D.	± S.D.	± S.D.	± S.D.	± S.D.	± S.D.		Robust 95% pred intervals
Units of issue	100 g	100 g	100 g	100 g	100 g	100 g	100 g	100 g	50 g
Form	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried
PCB 18	*47.4 ± 16.1	*17.5 ± 7.1	*9.0 ± 4.7	*3.7 ± 1.6	*3.0 ± 1.1			*2.1	
PCB 28	*48.7 ± 17.0	*25.6 ± 8.4	*18.6 ± 8.6	*6.8 ± 1.8	*5.3 ± 1.3			*5.2	
PCB 44	*64.7 ± 31.4	*45.5 ± 25.3	*32.6 ± 15.3	*7.5 ± 2.9	*7.3 ± 2.4			*10.4	
PCB 52	*99.4 ± 43.2	*56.0 ± 14.5	*35.6 ± 12.9	*12.5 ± 5.7	*13.3 ± 4.1			*14.2	
PCB 81									*0.133 ± 0.247[c]
PCB 87	*44.9 ± 14.5	*24.7 ± 6.5	*16.8 ± 3.7	*8.3 ± 1.5	*9.6 ± 1.4			*6.9	
PCB 101	*109.4 ± 74.4	*59.7 ± 29.1	*38.3 ± 7.2	*22.4 ± 9.5	*24.6 ± 6.0			*18.2	
PCB 105	*34.2 ± 13.5	*17.4 ± 4.8	*13.1 ± 4.3	*8.1 ± 3.2	*7.6 ± 2.7			*5.9	*6.097 ± 1.467
PCB 110	*120.1 ± 67.3	*77.8 ± 36.9	*52.5 ± 21.4	*29.1 ± 11.5	*33.3 ± 11.9			*18.8	
PCB 114									*0.284 ± 0.242
PCB 118	*79.8 ± 37.1	*40.5 ± 11.6	*28.5 ± 5.4	*17.8 ± 7.7	*17.0 ± 7.4			*12.5	*13.48 ± 7.40

(Continued on next page)

Table 10 (*continued*)

Code	EC-1	EC-2	EC-3	EC-4	EC-5	EC-6	EC-7	EC-8[b]	DX-3[a]
PCB 123									*0.484 ± 0.461
PCB 128	*14.5 ± 6.4	*7.9 ± 5.1	*7.3 ± 3.2	*4.6 ± 2.2	*5.5 ± 2.3			*2.7	
PCB 137	*3.8 ± 1.0	*2.4 ± 0.8	*4.8 ± 2.9	*1.7 ± 0.7	*1.7 ± 0.8				
PCB 138	*72.0 ± 26.3	*35.1 ± 11.8	*25.2 ± 6.3	*28.7 ± 9.7	*28.6 ± 9.1			*14.8	
PCB 141	*19.4 ± 4.0	*9.2 ± 3.4	*6.2 ± 2.0	*8.3 ± 2.0	*8.4 ± 1.9				
PCB 151	*16.6 ± 4.9	*9.9 ± 4.3	*8.1 ± 4.1	*9.4 ± 3.7	*8.4 ± 2.8			*2.5	
PCB 153	*68.2 ± 22.1	*33.3 ± 11.9	*24.2 ± 4.1	*27.3 ± 7.5	*27.2 ± 5.5			*11.4	
PCB 156									*1.126 ± 0.592
PCB 157									*0.332 ± 0.223
PCB 167									*0.587 ± 0.438
PCB 170	*16.8 ± 7.6	*8.4 ± 2.4	*8.9 ± 1.3	*11.8 ± 2.5	*10.1 ± 1.6			*4.3	
PCB 180	*44.9 ± 23.2	*20.8 ± 9.6	*15.4 ± 6.6	*26.1 ± 11.0	*22.3 ± 7.6			*7	
PCB 183	*15.2 ± 7.6	*6.7 ± 2.9	*4.9 ± 1.8	*8.4 ± 4.1	*7.2 ± 2.8			*1.8	
PCB 189									*0.185 ± 0.130
PCB 194	*13.1 ± 5.6	*14.3 ± 26.0	*5.2 ± 2.1	*6.9 ± 3.1	*8.1 ± 10.1			*2.3	
PCB 201	*7.3 ± 5.0	*9.9 ± 4.8	*8.3 ± 2.4	*8.1 ± 2.0	*5.7 ± 2.7			*0.5	
PCB 206	*7.0 ± 3.0	*5.6 ± 3.0	*5.2 ± 2.1	*3.2 ± 1.6	*2.2 ± 0.9			*3.7	
PCB 209	*1.4 ± 0.8	*16.1 ± 10.5	*18.7 ± 10.8	*1.6 ± 2.0	*1.2 ± 0.9			*9.3	
Total PCB	2000 ± 50	1160 ± 70	*660 ± 54	*577 ± 63	*597 ± 82	*105 ± 19	*21 ± 3	*621 ± 79	

For non-IAEA materials, values preceded by an asterisk (*) are non-certified; all other values are certified. For IAEA materials, values preceded by an asterisk are classified as information values; all other values are classified as recommended.

[a]'Information' values for an additional 53 PCBs are also available for DX-3.

[b]NWRI EC8 – these values are preliminary in nature and are provided as guideline only.

[c]NWRI note – this distribution implies less than 95% confidence.

Table 11
RMs for chlorinated dioxins and furans and non-ortho PCBs in sediments

Code	SRM 1944	EC-1[a]	EC-2[a]	EC-3[a]	DX-1	DX-2	DX-3
Organisation	SRM NIST	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI
Country of origin	USA	Canada	Canada	Canada	Canada	Canada	Canada
Matrix	New York, New Jersey, Waterway sediment	Harbour sediment	Lake sediment	River sediment	Great Lakes blend	Lake Ontario sediments	Great Lakes sediment
Units	µg/kg	ng/g	µg/g	µg/g	pg/g	pg/g	pg/g
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	95% CI	± S.D.	± S.D.	± S.D.	95% CI	95% CI	Robust 95% pred intervals
Units of issue	50 g	100 g	100 g	100 g	50 g	50 g	50 g
Form	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried
2,3,7,8-TCDF	*0.039 ± 0.015				*89 ± 44	*134 ± 61	*47 ± 31
Total TCDF	*0.7 ± 0.2				659 ± 259	975 ± 588	*555 ± 359
1,2,3,7,8-PCDF	*0.045 ± 0.007				39 ± 14	46 ± 10	*35 ± 17
2,3,4,7,8-PCDF	*0.045 ± 0.004				62 ± 32	88 ± 28	*45 ± 16
Total PCDF	*0.74 ± 0.07				790 ± 489	916 ± 351	*589 ± 369
1,2,3,4,7,8-HxCDF	*0.22 ± 0.03				714 ± 276	825 ± 348	*437 ± 151
1,2,3,6,7,8-HxCDF	*0.09 ± 0.01				116 ± 37	153 ± 61	*96 ± 46
1,2,3,7,8,9-HxCDF	*0.019 ± 0.018				*28 ± 42	*36 ± 45	*16 ± 32[b]
2,3,4,6,7,8-HxCDF	*0.054 ± 0.006				*57 ± 36	*70 ± 47	*39 ± 31
Total HxCDF	*1.0 ± 0.1				1800 ± 809	2111 ± 662	*1241 ± 477
1,2,3,4,6,7,8-HpCDF	*1.0 ± 0.1				2397 ± 796	3064 ± 745	*1923 ± 558
1,2,3,4,7,8,9-HpCDF	*0.040 ± 0.006				137 ± 62	152 ± 84	*98 ± 39
Total HpCDF	*1.5 ± 0.1				3567 ± 1165	4068 ± 1306	*2455 ± 737
OCDF	*1.0 ± 0.1				7122 ± 2406	7830 ± 3087	*3875 ± 1328
2,3,7,8-TCDD	*0.133 ± 0.009				263 ± 53	262 ± 51	*121 ± 43
Total TCDD	*0.25 ± 0.01				416 ± 121	418 ± 125	*251 ± 157
1,2,3,7,8-PCDD	*0.019 ± 0.002				22 ± 8	28 ± 14	*19 ± 7
Total PCDD	*0.19 ± 0.06				226 ± 143	253 ± 150	*204 ± 143
1,2,3,4,7,8-HxCDD	*0.026 ± 0.003				23 ± 7	25 ± 8	*20 ± 10
1,2,3,6,7,8-HxCDD	*0.056 ± 0.006				77 ± 27	85 ± 33	*60 ± 18
1,2,3,7,8,9-HxCDD	*0.053 ± 0.007				53 ± 24	58 ± 19	*37 ± 16
Total HxCDD	*0.63 ± 0.09				669 ± 185	739 ± 218	*547 ± 158
1,2,3,4,6,7,8-HpCDD	*0.80 ± 0.07				634 ± 182	757 ± 320	*501 ± 129
Total HpCDD	*1.8 ± 0.2				1251 ± 933	1486 ± 476	*942 ± 283
OCDD	*5.8 ± 0.7				3932 ± 933	4402 ± 1257	*3067 ± 888
Total CDFs	*5.0 ± 0.9				13 676 ± 3777	15 981 ± 4177	
Total CDDs	*8.7 ± 0.9				6490 ± 1309	7294 ± 1783	
Total toxic equivalent	*0.25 ± 0.01						
PCB 77		*4.1	*4.8	*4.5			*2560 ± 990
PCB 126		*0.7	*0.175	*0.175			*107 ± 80
PCB 169		* < 0.016	*0.020	*0.018			*14 ± 13

Values preceded by an asterisk (*) are non-certified; all other values are certified.
[a]NWRI EC1–3 non-ortho PCBs – these values are preliminary in nature and are provided as guideline only.
[b]NWRI note – this distribution implies less than 95% confidence.

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Table 12
RMs for chlorinated benzenes in sediments

Code	EC-1	EC-2	EC-3	EC-4	EC-5	EC-6	EC-7	EC-8
Organisation	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI	NWRI
Country of origin	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Matrix	Freshwater harbour sediment	Lake Ontario sediment	Lake Ontario sediment	Freshwater harbour sediment	River sediment	Lake Erie sediment	Lake St. Clair sediment	Lake Ontario sediment
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
As	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight	Dry weight
[±] expressed as	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.	±S.D.
Units of issue	100 g	100 g	100 g	100 g	100 g	100 g	100 g	100 g
Form	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried	Freeze-dried
1,2-Dichlorobenzene	*4.9 ± 1.8	18.1 ± 1.3	21 ± 3	*6.8 ± 1.8	*7.4 ± 2.5		*7.8 ± 4.1	*5 ± 1
1,3-Dichlorobenzene	*5.9 ± 3.0	74.7 ± 5.1	105 ± 18	*6.8 ± 1.4	*7.1 ± 1.9		*5.7 ± 3.7	*43 ± 3
1,4-Dichlorobenzene	*30.9 ± 9.5	84.4 ± 8.8	*108 ± 12		*29.0 ± 5.5		*22.4 ± 10.5	*58 ± 4
1,2,3-Trichlorobenzene	*2.3 ± 1.0	6.1 ± 0.7	9 ± 1	*1.9 ± 0.4	*3.8 ± 0.8		*4.4 ± 4.1	*3 ± 0.3
1,2,4-Trichlorobenzene	*3.4 ± 2.0	80.7 ± 5.4	*141 ± 14	*6.7 ± 1.1	*8.3 ± 0.7	*2.1 ± 0.8	*5.7 ± 2.0	*67 ± 4
1,3,5-Trichlorobenzene	*2.7 ± 0.7	34.3 ± 2.6	114 ± 10	*4.4 ± 0.9	*6.8 ± 1.3	*1.5 ± 0.7	*13.6 ± 4.0	*46 ± 2
1,2,3,4-Tetrachlorobenzene	*1.5 ± 0.4	36.5 ± 2.4	44 ± 5	*1.6 ± 0.4	*2.5 ± 0.3	*0.4	*1.6 ± 1.2	*17 ± 1
1,2,3,5-Tetrachlorobenzene	*0.8 ± 0.4	5.2 ± 0.4	*14 ± 1	*0.3 ± 0.2	*0.6 ± 0.1			*6 ± 0.3
1,2,4,5-Tetrachlorobenzene	*3.4 ± 1.6	84.0 ± 4.9	*156 ± 17	*2.4 ± 0.9	*3.3 ± 0.5	*1.5 ± 0.4	*19.2 ± 9.9	*57 ± 4
Pentachlorobenzene	*1.7 ± 0.4	48.6 ± 2.4	65 ± 8	*1.9 ± 0.4	*2.2 ± 0.3	*1.4 ± 0.2	*9.1 ± 3.9	*30 ± 3
Hexachlorobenzene	*5.4 ± 1.9	200.6 ± 13.2	279 ± 33	*2.2 ± 0.6	*2.4 ± 0.2	*3.6 ± 1.1	*53.3 ± 18.7	*98 ± 9
Hexachlorobutadiene	*0.66 ± 0.56	21.3 ± 1.6	61 ± 7	*0.6 ± 0.1	*0.88 ± 0.2	*1.7 ± 1.1	*7.0 ± 3.3	*21 ± 2
Hexachloroethylene						*0.63 ± 0.3	*1.0 ± 0.4	
Octachlorostyrene	*6.0 ± 1.4	*30.6 ± 4.6	*41 ± 6	*1.0 ± 0.3	*0.89 ± 0.1	*3.4 ± 2.7	*17.5 ± 7.0	*22 ± 4

Values preceded by an asterisk (*) are non-certified; all other values are certified.

Table 13
RMs for organic compounds in marine sediments

Code	BCR 462
Organisation	BCR
Country of origin	EU
Matrix	Coastal sediment
Units	µg / kg
As	Dry weight
[±] expressed as	Expanded uncertainty[a]
Units of issue	25 g
Form	Air-dried
TBT	54 ± 15
DBT	68 ± 12

Values preceded by an asterisk (*) are non-certified; all other values are certified.

[a]Expanded uncertainty $U = k{\cdot}u_c$ calculated according to ISO/BIPM guide with coverage factor $k = 2$.

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