REPORT LNR 3621-97

Rao Quan Feasibility Study
Phase 1

Toxic Substances and Contamination

FINAL REPORT

Norwegian Institute for Water Research

REPORT

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Abstract

The three rivers Rao Quan, Khe Nghi, and Quang Tri contain relatively soft water with a calcium content from 3 - 17 mg/l. The pH value varies from 7-9. The alkalinity varies from 0.4-1.4 mMol/l which indicates good buffer capacity against acidification. The sulphate concentration is also low. The water will not be aggressive against concrete material. The turbidity of the water varies from 1.8 FTU in the dry season to 16 FTU in the wet season. This indicates a maximum particulate content of 17 mg/l in the wet season, which is rather low. The nutrient content of the rivers is relatively low. The phosphorus content (8-35 µgP/l) correlated well with the turbidity, which indicates that the phosphorus is bound to particles. Khe Nghi has significantly higher nitrogen content (380 µgN/l) than the other rivers, which may indicate some slight impact from animal husbandry. However, no sign of eutrophication is noticed. The content of heavy metals is low and indicates no pollution from the military activity in the area. The water has a good quality for irrigation purposes. There was no indications from the analysed fish, river sediments or rice field top soil samples from the Rao Quan area of dioxin contamination of any practical significance. The content was similar to back ground levels that can be found everywhere due to diffuse atmospheric fallout. In relation to spreading of Agent Orange in 1962-1975 during the war, contamination in Quang Tri Province is hardly to be expected, as the application of this herbicide mainly took place in the southernmost part of the country.

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Rao Quan Feasibility study, Phase 1

TOXIC SUBSTANCES AND CONTAMINATION

Final Report

Oslo, Norway, June 28 1997

Project leader: Dag Berge
Co-workers: Jon Knutzen
Vo Van Tai, People's Committee of Quang Tri Province

Preface

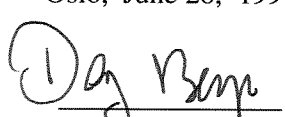
Analysis of toxic substances and contamination were performed under a sub-contract with Statkraft Engineering for the feasibility Study, Phase 1 of Rao Quan Hydropower Development. The aim of the study is to clarify the water quality of the rivers, and to assess the possibility of getting washed out contaminants from the war time activities in the catchment of the planned reservoir. In the overall project, Norwegian Institute for Water Research (NIVA) serve as an independent environment consultant. The study is financed by The Norwegian Agency for Development Co-operation (NORAD).

The field work is performed by Dag Berge, NIVA, and Vo Van Tai, People's Committee of Quang Tri Province. The chemical analysis are partly done in Vietnam (PIDC1 - Laboratory Department, Hanoi) and partly at NIVA. In fact, several parameters were performed at both laboratories for intercalibration purposes. The dioxin analysis were performed at Norwegian Institute for Air Research, NILU.

The chapter dealing with dioxin pollution is written by Jon Knutzen, NIVA, the remainder of the report is prepared by Dag Berge.

I would like to express my gratitude to the people at PIDC1 in Hanoi, and to the People's Committee of Quang Tri Province, who provided excellent service and support during the field work. Likewise I would like to thank the Assistant Team Leader, Lars Ødegård, and his staff, particularly Sven Erik Hetager, at Statkraft Engineering for good assistance in organising all practical aspects of the work in Vietnam.

Oslo, June 28, 1997



Dag Berge

Contents

1. Conclusion

The three rivers Rao Quan, Khe Nghi, and Quang Tri contain relatively soft water with a calcium content from 3 - 17 mg/l. The pH values vary from 7-9. The alkalinity varies from 0.4-1.4 mMol/l which indicate good buffer capacity against acidification. The sulphate concentration is also low. The water will not be aggressive against concrete material.

The turbidity of the water varies from 1.8 FTU in the dry season to 16 FTU in the wet season. This indicate a maximum particulate content of 17 mg/l in the wet season, which is rather low for rivers in Asia. If shoreline erosion in the reservoir can be controlled, river transport of sediments will not be a great problem with respect to fill in the reservoir.

The nutrient content of the rivers is relatively low. The phosphorus content (8-35 µgP/l) correlated well with the turbidity, which indicates that the phosphorus is bound to particles. Khe Nghi had significantly higher nitrogen content (380 µgN/l) than the other rivers, which can indicate some slight impact from animal husbandry. However, no sign of eutrophication was noticed.

The content of heavy metals is low and indicates no pollution form the military activity in the area during the war.

In general the water quality is good and the water is suitable for irrigation purposes.

There are no indications of dioxin contamination of any practical significance from the analysed fish, river sediments or rice field top soil samples. The content was similar to back ground levels that can be found everywhere due to diffuse atmospheric fallout. In relation to spreading of Agent Orange from 1962-1975 during the war, contamination in Quang Tri Province is hardly to be expected, as the application of this herbicide mainly took place in the southernmost part of the country (Westing, 1984).

2. Introduction

Due to wartime activity in the Khe Sanh area, it was expected that damming of Rao Quan could wash out diffuse pollutants from the ground and from possible military dumpsites. The area is also heavily affected by deforestation. Most of this is due to logging and collection of fire wood, as well as slash and burn agriculture. However, It was also believed that the dioxin containing defoliator chemical "Agent Orange" had been applied. There exist, however, no studies that confirm the above mentioned contamination.

To reveal a potential pollution danger due to damming and washout from the two catchments of upper Rao Quan River and Khe Nghi River, a simple sampling programme was included in phase 1 of the feasibility study. This includes water quality of the two rivers, contaminants in the river sediments and in filets of common river fish species, and, also possible dioxin remnants in downstream rice field top soil irrigated by water from the actual rivers.

The study should also give a general description of the water quality of the rivers.

3. Field work - Collection of samples - Analysis

The first part of the field work was carried out in mid July 1996 during the initial site visit.

A local counterpart was contracted at the Quang Tri Province authorities, Mr. Vo Van Tai (People's Committee of Quang Tri Province) who provided assistance on the field trip along Rao Quan and Khe Nghi. He also collected the water samples in the rainy season (September/October).

In July, the following samples were taken:

Type of sample	**Location**
Water samples	Rao Quan (Damsite) Khe Nghi (Damsite) Quang Tri (Da Krong Bridge)
Sediment samples	Rao Quan (Damsite) Khe Nghi (Damsite)
Fish samples (filet, liver)	Rao Quan (Damsite) Khe Nghi (Damsite)
Soil samples	Hai Tri (rice field irrigated by water from the actual rivers, part of the Thach Han irrigation system)

In September/October, only water samples were taken from the three rivers. The sample from Khe Nghi river was then taken at Khe Nghi Bridge just upstream the confluence with Quang Tri river. Thus, the results from the Khe Nghi river during dry and wet season are not quite comparable due the fact that they are not taken from the same site. In the wet season the damsite of Khe Nghi was not accessible.

Chemical analyses were partly done in Vietnam (PIDC1 - Laboratory Department) and partly at NIVA. In fact several parameters were performed at both laboratories for intercalibration purposes.

dioxin analysis are performed at Norwegian Institute for Air Research, NILU. Both NIVA's and NILU's Laboratories are accredited after international norms.

Figure 1. In the river Rao Quan the samples were taken in the deepest part in the big pool 300 m upstream of the planned damsite.

Figure 2. In Khe Nghi the samples were taken just upstream the planned damsite.

Figure 3. In Quang Tri River the samples were taken at Da Krong Bridge.

Figure 4. The rice field soil sample was taken in Hai Tri where the rice fields are irrigated by water from the actual rivers (part of the Thach Han irrigation system).

4. Results

4.1 Military dump sites

The dump sites from the American Khe Sanh Base were, according to local information, located downstream of the damsite. Thus the damming of Rao Quan will not impose any contamination danger due to wash out from dump sites. The dumps have in fact more or less been emptied by local "treasure hunters" who have sold metals and other debris. Now the dumps are overgrown by natural vegetation and can hardly be found. According to our local counterpart, it was not possible to find any surface seepage from the former dump areas.

4.2 Water Quality in the rivers

Samples for water quality assessment of the rivers are collected from a low flow period at the end of the dry season (July 1996), and from the wet season (September/October 1996).

The samples were partly analysed at The Laboratory Department at PIDC1 (Power Investigation and Design Company no 1). The local laboratory did not have operative methodologies for all the requested parameters. Consequently analysis had to be performed at the accredited laboratory at NIVA (Norwegian Institute for Water Research). For most of the parameters where both laboratories had operative methodologies, it was good agreements between the results, but big differences did also occur for some important parameters. For this reason the discussion of the results is based on the results from NIVA.

The results of the general water quality analysis are shown in Table 1, and primary data can be found in the Appendix, Enclosure no. 1 (NIVA-Lab), and no. 2 (PIDC1-Lab).

All three rivers have relatively soft water with good buffer capacity against acidification. pH is above neutrality, the alkalinity is good, and the sulphate content is low. The water will not be aggressive against concrete material and can safely be used as water addition to the concrete mix.

Khe Nghi river at the damsite is more turbid during the dry season than the two other rivers which indicate content of erosion material. In this period Rao Quan had low turbidity (1.8 FTU) which indicate rather low content of erosion material. In the rainy season the turbidity of Rao Quan increased to approximately 16 FTU which is still relatively low. There were no successful direct measurement taken of the water's particulate content, but a turbidity of 16 FTU indicate a content of suspended solids of about 17 mg/l according to linear regression between the two parameters (Holtan 1996).

Table 1. Chemical analysis of river water (Standard parameters), sampled July 18-19 (dry season), and September 2 (wet season) 1996.

	Short name	Unit	Rao Quan (Damsite)		Khe Nghi (Damsite)		Quang Tri (Da Krong Bridge)	
			July 1996	September 1996	July 1996	September 1996	July 1996	September 1996
pH	pH		8.10	8.6	7.35	8.03	8.05	9.0
Conductivity	cond	mS/m (25)	13.14	6.47	6.09	5.03	11.82	6.25
Turbidity	turb	FTU	1.8	15.8	13	15.8	4.1	14.4
Alkalinity	alk	mmol/l	1.35	0.658	0.48	0.43	1.144	0.656
Cloride	Cl	mg/l	1.8	1.8	3.0	2.7	2.4	2.1
Sulphate	SO4	mg/l	0.9	0.7	0.8	0.9	2.0	1.3
Nitrate	NO3	µgN/l	23	63	55	145	4	104
Total nitrogen	tot-N	µgN/l	137	205	295	380	147	295
Total phosphorus	tot-P	µgP/l	8	17	29	35	17	35
Calsium	Ca	mg/l	17.7	7.61	3.13	3.32	12.7	8.19
Magnesium	Mg	mg/l	3.6	1.9	1.11	1.12	3.06	2.37
Sodium	Na	mg/l	4.42	3.58	6.62	5.57	4.36	4.07
Potassium	K	mg/l	1.19	1.01	1.82	1.42	1.24	1.20
Total organic cabon	TOC	mgC/l	1.0	1.0	1.4	1.5	1.0	1.3

In Quang Tri River at Da Krong Bridge, the turbidity did also increase during the high flow period, but to a less extent than in Rao Quan. As the Khe Nghi damsite was not accessible in the rainy season, the samples from the high flow period were taken from Khe Nghi Bridge just upstream the confluence with Quang Tri river. In both the dry and wet season the particulate content was less there than in the damsite area.

The sediment load of approximately 17 mg/l in this high flow period is rather low, as for example compared to the average load of 100 mg/l in the Yangtze River which is going to be dammed at Three Gorges in China. The particulate content of neither Rao Quan river nor Khe Nghi river should be a problem with respect to filling up the planned reservoirs with sediments.

The rivers are poor in nutrient content. Khe Nghi, however, have higher content of both phosphorus and nitrogen than the two other rivers. The phosphorus content can be explained by particulate P bound to erosion material. However, the relatively high nitrogen content in Khe Nghi, is difficult to explain from natural processes alone. It may be affected by animal husbandry in the catchment area, and / or runoff from construction work (blasting, if such activity has started).

The water quality of all three rivers are well suited for irrigation purposes. None of the rivers seem to be affected by human discharges to any significant level. This picture will, however, change if modern sanitary systems are implemented without the necessary effluent treatment.

The content of heavy metal was low and indicated no contamination from metal debris due to war time activities. Where such contamination is of importance it is most often seen as an elevated level of lead and copper. Lead and copper in these rivers show concentrations typical for natural background runoff.

Table 2. Concentrations of heavy metals in the river water, sampled 18-19 July 1996. Analysis performed at NIVA.

	Short name	Unit	Rao Quan (Damsite)	Khe Nghi (Damsite)	Quang Tri (Da Krong Bridge)
Cromium	Cr	µg/l	0.2	<0.1	0.3
Manganeese	Mn	µg/l	36	73	42
Iron	Fe	µg/l	266	732	232
Nickel	Ni	µg/l	0.51	0.22	0.63
Copper	Cu	µg/l	0.3	0.4	0.7
Zinc	Zn	µg/l	0.9	1.4	2.1
Arsen	As	µg/l	0.3	0.2	1.0
Cadmium	Cd	µg/l	0.01	0.01	0.01
Tinn	Sn	µg/l	<0.5	<0.5	<0.5
Lead	Pb	µg/l	0.31	0.75	0.47

With respect to other metals, the concentration of iron is high, particularly in Khe Nghi. This is likely due to natural geological conditions and not pollution. The reddish soil attains its colour from iron, and the high iron content in Khe Nghi corresponds well to the fact that this river had the highest soil content as shown in the turbidity values.

4.3 Dioxin contamination

To reveal any dioxin contamination from the use of the defoliator Agent Orange during the war, it was taken samples of river sediments and fish filets. It was also included a mixed top soil sample from a rice field at Hai Tri, part of Thach Han irrigation system, which are irrigated by water from the actual rivers.

4.3.1 Dioxins and dibenzofurans (PCDD/PCDF) in fish, river sediments and rice field top soil.

The following samples have been analysed for polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF) at the Norwegian Institute for Air Research:

- Filet of fish (local name Ca chay) from the rivers Rao Quan and Khe Nghi in July 1996 (samples nos. 1,2, respectively, in table 3 and 4)
- Surface sediments from the same rivers (samples nos. 3,4, respectively Rao Quan and Khe Nghi)
- Soil from rice field (sample 5)

Table 3. Fat content of fish filets and organic content of sediments.

No	Medium	Extractable Fat (%)	Organic content (%)
1	Fish filet from Rao Quan	1.3	
2	Fish filet from Khe Nghi	1.0	
3	Sediment from Rao Quan		1.2
4	Sediment from Khe Nghi		3.0
5	Rice field soil from Hai Tri		3.8

The results recalculated to toxicity equivalents (TE) according to the Nordic model (Ahlborg, 1989) show low contamination levels (Table 4, raw data in Appendix, Enclosure no. 3).

Even for fish with a low/intermediate fat content (1.3 and 1.0 %, respectively in sample 1/2), 0.1 ng TE/kg wet weight and below is a very low dioxin content. Assumed high background level in low fat (< 1 %) Norwegian fish (from areas with only diffuse loading, i.e. no point source influence) is 0.1-0.2 ng TE/kg w.w. (Knutzen, 1995). Low PCDD/PCDF values in fish from markets in northern and southern Viet Nam 1985-1987 have previously been reported by Olie et al. (1989).

The two sediment samples had different TE-levels. However, the figures are difficult to compare without information of the content of organic substance. Persistent organochlorines tend to associate with the organic fraction, which is highly variable in river sediments. In any case 0.26 and 1.89 ng TE/kg dry weight is in the low-moderate range. High background levels in Norwegian coastal sediments is assumed to be 5-10 ng/kg d.w. (Knutzen, 1995). In a baseline study of river (estuarine) surface sediments in Taiwan, Huang et al. (1995) recorded $TE_{PCDD/F}$ levels in the range 0.03-9.63 ,

mostly below 1 ng/kg d.w. For remote lake sediments in the USA, Cleverly et al. (1996) reported 0.1 -15.6 ng TE/kg, also noting that 2378-congeners accounted for about 50-90 % of total PCDD/PCDFs. In the above sediment samples from Rao Quan and Khe Nghi sum of compounds with 2378-configuration were 117 and 1465ng/kg d.w., respectively. Assuming 50 % contribution from the 2378-congeners this gives a total content of about 250 ng/g and 3000 ng/g PCDD/PCDFs in the sediment samples from Rao Quan and Khe Nghi, respectively. In comparison Czuczwa et al (1985) recorded about 700 ng/kg d.w. in a lake only receiving atmospheric inputs.

Table 4. PCDD/PCDD as toxicity equivalents (TE, Ahlborg, 1989) in Ca chay (fish) filet (sample nos. 1 and 2) and surface sediments (samples nos. 3 and 4) from the rivers Rao Quan and Khe Nghi, and Rice field top soil from Hai Tri (sample no. 5), July 1996, ng/kg wet weight in fish an ng/kg dry weight in sediment/soil.

Compounds	Fish filet Rao Quan	Fish filet Khe Nghi	Sediment Rao Quan	Sediment Khe Nghi	Rice field Soil (Hai Tri)
PCDD/PCDFs	1	2	3	4	5
2378-TCDD	0,02	0,04	0,03	0,23	0,49
12378-PeCDD	0,01	0,01	0,02	0,02	0,13
123478-HxCDD	0,00	0,00	0,01	0,01	0,02
123678-HxCDD	0,00	0,00	0,01	0,01	0,06
123789-HxCDD	0,00	0,00	0,01	0,01	0,09
1234678-HpCDD	0,00	0,00	0,01	0,12	0,13
OCDD	0,00	0,00	0,12	1,43	0,39
2378-TCDF	0,01	0,00	0,00	0,02	0,03
12378/12348-PeCDF	0,00	0,00	0,00	0,00	0,00
23478-PeCDF	0,00	0,01	0,02	0,02	0,02
123478/123479_HxCDF	0,00	0,01	0,02	0,01	0,04
123678-HxCDF	0,00	0,00	0,01	0,01	0,02
123789-HxCDF	0,00	0,00	0,01	0,01	0,00
234678-HxCDF	0,00	0,00	0,01	0,01	0,00
1234678-HpCDF	0,00	0,00	0,00	0,00	0,01
1234789-HpCDF	0,00	0,00	0,00	0,00	0,00
OCDF	0,00	0,00	0,00	0,00	0,00
Σ TE	0,07	0,10	0,26	1,89	1,44

The predominance of OCDD and the contribution from hexa- and hepta-compounds in the sediment profiles (Table 4) mainly indicates origin from combustion and atmospheric input (Czuczwa and Hites, 1984), but small local sources cannot be excluded (cf. contribution from 2378-TCDD, particularly in sample 5 of rice field soil). In a previous study of Vietnamese river sediments from 1984-86 Schechter et al (1989a) also related their findings mostly to combustion/atmospheric loading. They found low concentrations in grab collected sediments from the Red River in the north (up to 255 ng/kg d.w. of sum PCDD/PCDFs), somewhat higher but still moderate values in rivers from the southern part: 850-1400 ng/kg d.w. in Dong Nai River and 6800 ng/kg in Saigon River. (By

reanalyses of the material Schechter ad co-workers (1989b) found the originally not registered 2378-TCDD in the sediments from Saigon River but not from the two others).

The concentration of 1.44 ng TE/kg d.w. registered in rice field soil is also low, considering that United States health authorities have calculated that three orders of magnitude higher concentration of 2378-TCDD represents a negligible increase in cancer risk (Gough, 1986, p. 240). From an extensive survey based on sampling in different parts of Vietnam 1989-1991 Matsuda et al. (1994) reported no detectable concentrations of 2378-TCDD in 5 samples from the Hanoi area in contrast to 1,2-59 ng/kg d.w. in 20 out of more than 100 samples from the Hue area and particularly from the southern part of Vietnam. OCDD was recorded in all samples, also in the vicinity of Hanoi, in concentrations 11 to above 10^4 ng/kg dry weight. Likewise, HpCDD were found in all parts of the country. From Olie (1984) it appears that previous soil data are rather scarce. In samples from 1980-81 it was found <1-31 ng 2378-TCDD/kg d.w.

In conclusion, there is no indications from the analysed fish, sediment and soil samples from the Rao Quan area of dioxin contamination of any significance. In relation to spreading of Agent Orange in 1962-1975 during the war, this is neither to be expected. The input of the estimated total of 170 kg 2378-TCDD (Westing, 1984) mainly came in the heavily sprayed southern part of the country and was concentrated on about 17000 km^2, i.e. about 10 % of the total land area of the former South Vietnam (Westing, 1984).

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6. Appendix - Primary Data

NIVA

Analysis Report

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Our Reference:
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Date
21/03/97

The samples was delivered at NIVA's laboratory by the client, and marked according to the table below. The samples was analysed with the following results (analytical uncertainty and precision is given in a separat document, and can be delivered on request):

Sample no	Sample marked	Sampling-date	Received at NIVA	Analysis period
1	1.RAO QUAN	18/7-97		
2	2.KHE NGHI	18/7-97		
3	3.DA KRONG	18/7-97		

Methode no	Sample no Parameter	1	2	3
A 1	pH	8.10	7.35	8.05
A 2	Conductivity mS/m	13.14	6.09	11.82
C 1	Alkalinity mmol/l	1.350	0.480	1.144
A 4	Turbidity FTU	1.8	13.0	4.1
D 2-1	Total Phosphorus µg/l P	8	29	17
D 6-1	Total Nitrogen µg/l N	137	295	147
D 3	Nitrat µg/l N	23	55	4
G 4	Total Organic Carbon mgC/l	1.0	1.4	1.0
C 4	Cloride mg/l	1.8	3.0	2.4
C 4	Sulphate mg/l	0.9	0.8	2.0
E 1	Potassium mg/l	1.19	1.82	1.24
	Calsium mg/l	17.7	3.13	12.7
	Magnesium mg/l	3.60	1.11	3.06
	Sodium mg/l	4.42	6.62	4.36
	Reactive Aluminum µg/l	10	13	13
	Illabile Aluminum µg/l	11	<10	<10
Internal	Cromium µg/l	0.2	<0.1	0.3
Internal	Manganese µg/l	36	73	42
Internal	Iron µg/l	266	732	232
Internal	Nickel µg/l	0.51	0.22	0.63
Internal	Copper µg/l	0.3	0.4	0.7
Internal	Zink µg/l	0.9	1.4	2.1
Internal	Arsen µg/l	0.3	0.2	1.0
Internal	Cadmium µg/l	0.01	0.01	0.01
Internal	Tin µg/l	<0.5	<0.5	<0.5
Internal	Bly µg/l	0.31	0.75	0.47

Norwegian Institute for Water Research

Rainer Lichtenthaler
Head of Department

NIVA

Analysis Report

NORSK AKKREDITERING Nr. P009

Norwegian Institute for Water research
P.O. BOX 173 Kjelsås
0411 Oslo , NORWAY
Tel: 22 18 51 00
Fax: 22 18 52 00

Name
Address

Your reference:

Our Reference: Rekv.no. 1996-02406 O.no .O 96110

Date 21/03/97

The samples was delivered at NIVA's laboratory by the client, and marked according to the table below. The samples was analysed with the following results (analytical uncertainty and precision is given in a separat document, and can be delivered on request):

Sample no	Sample marked	Sampling-date	Received at NIVA	Analysis period
1	1.RAO QUAN	2/9-96	14/11-96	
2	2.KHE NGHI	2/9-96	14/11-96	
3	3.DA KRONG	2/9-96	14/11-96	

Methode no	Sample no Parameter	1	2	3
A 1	pH	7.57	8.03	9.0
A 2	Conductivity mS/m	6.47	5.03	6.25
C 1	Alkalinity mmol/l	0.658	0.430	0.656
A 4	Turbidity FTU	15.8	15.8	14.4
D 2-1	Total Phosphorus µg/l P	17	35	35
D 6-1	Total Nitrogen µg/l N	205	380	295
D 3	Nitrat µg/l N	63	145	104
G 4	Total Organic Carbon mgC/l	1.0	1.5	1.3
C 4	Cloride mg/l	1.8	2.7	2.1
C 4	Sulphate mg/l	0.7	0.9	1.3
E 1	Potassium mg/l	1.01	1.42	1.2
	Calsium mg/l	7.61	3.32	8.19
	Magnesium mg/l	1.9	1.12	2.37
	Sodium mg/l	3.58	5.57	4.04
	Reactive Aluminum µg/l			
	Illabile Aluminum µg/l			
Internal	Cromium µg/l			
Internal	Manganese µg/l			
Internal	Iron µg/l			
Internal	Nickel µg/l			
Internal	Copper µg/l			
Internal	Zink µg/l			
Internal	Arsen µg/l			
Internal	Cadmium µg/l			
Internal	Tin µg/l			
Internal	Bly µg/l			

Norwegian Institute for Water Research

Rainer Lichtenthaler
Head of Department

Enclosure no 2.

POWER INVESTIGATION AND DESIGN COMPANY N°1
LABOLATORY DEPARTMENT
Thanh Xuan, Dong Da, Hanoi
Phone: 84 4 543 952 Fax: 84 4 541208

To: ***Mr.Sven Erik Hetager***
Environmental Specialist
To: ***Mr.Sven Erik Hetager***

Date: **26/7/1996**

Statkraft engineering

RESULTS OF ANALYTIC WATER

Name of project: ***Rao Quan Hydropower Project***
Date of delivered samples: ***22/7/1996***
Date of implemented test: ***23/7/1996***
Name of test implemented person: ***Mr. Pham Viet An***
Name of test requested person: ***Mr. Sven Erik Hetager***

PROPERTIES		UNIT	RAO QUAN DAMSITE	KHE NGHI DAMSITE	DAKRONG RIVER (at Dakrong bridge)
MAIN IONIC	Ca	mg/l	19.24	4.41	15.23
COMPOSITION	Mg	mg/l	2.92	0.73	2.92
	Na	mg/l	5.54	7.34	5.60
	K	mg/l	2.02	2.54	2.16
	Fe	µg/l	31.0	119.0	10.0
	Mn	µg/l	12.0	15.0	9.0
	Cl	mg/l	3.32	6.63	4.97
	HCO_3	mequ/l	1.40	0.50	1.20
	SO_4	mg/l	0.0	0.0	0.0
NUTRIENTS	Total Phosphorus	µg/l	0.0	0.0	0.0
	Total Nitrogen	Mg/l	0.0	700.0	0.0
SEDIMENTS	Particulate Matter(ss)	PMmg/l	0.0	5.0	0.0
	Particulate Organic	POMmg/l	-	-	-
	Particulate Inorganic	PIMmg/l	-	-	-
GENARAL	pH		8.0	7.7	7.9
	Conductivity	ms/l	0.155	0.105	0.141
	Colour	mg Pt/l	6.6	29.20	7.30

Not : -Colour : Determined by Cobalt
-Particulate matter: This value too small so Particulate Organic and Inorganic can not be Determined
- Turbidity PIDC1 's labolatory has not suitable equiment , so this value can not be determined .

Chief of laboratory

Mirs . Pham Thi Hop

Done by

Mirs . Tran Thi Vang

Enclosure no 2, continued.

POWER INVESTIGATION AND DESIGN COMPANY N°1
LABOLATORY DEPARTMENT
Thanh Xuan, Dong Da, Hanoi
Phone: 84 4 543 952 Fax: 84 4 541208

To: ***Mr.Sven Erik Hetager***
Environmental Specialist
To: ***Mr.Sven Erik Hetager***

Date: **13/11/1996**

Statkraft engineering

RESULTS OF ANALYTIC WATER

PROPERTIES		UNIT	RAO QUAN DAMSITE	KHE NGHI BRIDGE	DAKRONG BRIDGE	RAO QUAN	KHE NGHI BRIDGE	DAKRONG BRIDGE
SAMPLE - N_0			1	2	3	4	5	6
DATE OF TAKEN SAMPLE			2/9/96	2/9/96	2/9/96	10/96	10/96	10/96
DATE OF TESTING			12/11/96	12/11/96	12/11/96	12/11/96	12/11/96	12/11/96
	Ca	mg/l	9.22	2.43	10.02	8.02	3.61	6.81
	Mg	mg/l	1.46	0.97	2.43	0.97	1.22	1.95
	Na	mg/l	5.92	6.88	6.76	6.12	5.11	6.53
	K	mg/l	3.44	3.04	3.00	2.88	2.73	2.61
	Fe	µg/l	26.67	173.33	26.67	133.35	320.00	106.68
	Mn	µg/l	48.00	45.00	50.00	65.00	68.00	16.00
	Cl	mg/l	3.27	3.27	4.90	4.90	3.27	4.90
	HCO^3	mequ/l	0.83	0.56	0.94	0.69	0.42	0.73
	SO_4	mg/l	<0.05	1.50	<0.05	<0.05	2.00	<0.05
NUTRIENTS	Total Phosphorus	µg/l	170.28	257.60	257.60	104.79	87.32	82.96
	Total Nitrogen	µg/l	350	700	700.	1050	1400	1050
SEDIMENTS	Particulat Matter(ss)	PM (mg/l)	0.00	5.00	10.00	0.00	0.00	0.00
	Particulate Organic	POM(mg/l)	-	-	-	-	-	-
	Particulat Inorganic	PIM (mg/l)	-	-	-	-	-	-
GENARAL	pH		7.8	7.4	7.3	7.1	6.4	6.7
	Conductivity	ms/m	0.052	0.035	0.056	0.030	0.019	0.036
	Colour	mg Pt/l	8.60	25.50	14.60	31.40	64.40	28.80

Note : -Colour : Determined by Cobalt
-Particulate matter: This value too small so Particulate Organic and Inorganic can not be Determined
- Turbidity PIDC1 's labolatory has not suitable equiment , so this value can not be determined .

Chief of Laboratory

Mrs . Pham Thi Hop

Checked by

Mrs . Tran Thi Vang

Tested by

Mrs.Nguyen Thi Nhung

NORSK AKKREDITERING P 008

Accreditation according to EN 45001

Norwegian Institute for Air Research
P.O. Box 100, N-2007 Kjeller

NILU

Measuring report No. O-296

Customer: Norwegian Institute for Water Research (NIVA)
Att.: Dag Berge
P.O. Box 173 Kjelsås
0411 OSLO

Project No.: O-1875

Sampling:
Location: Vietnam
Responsibility: NIVA
Comments:

Sample information:

NILU Sample ID	Customer's Sample ID	Sample type	Sample received	Sample analysed
96/697	Rao-Quan	Filet of fish	2308.96	27.09.-27.11.96
96/698	Khe Nghi	"	"	"
96/699	1. Rao-Quan.	Sediment	"	24.09.-27.1196
96/700	1. Khe-Nghi	"	"	"
96/701	From rice paddy	Soil/sediment	"	"

Analyses:
Performed by: Norwegian Institute for Air Research
P.O. Box 100
N-2007 KJELLER

Method: NILU-O-1 ("Determination of polychlorinated dibenzo-p-dioxins and dibenzofuranes")
Uncertainty: ±25%
Comments: The results for sample No. 96/700 does not fulfil our requirements for recovery. The recovery is 32-38 %.

Accepted: Kjeller, 6 December 1996

Ole-Anders Braathen

Ole-Anders Braathen
Head, Chemical Analysis

Enclosures: Results of analyses: 10 pages
Measuring report and enclosures cover 12 pages totally

Measuring results represent only the samples analysed. This report shall not be reproduced except in full, without the written approval of the measuring laboratory

Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/697
Customer: NIVA
Customers sample ID: Rao Quan - Vietnam
: Fish - fillet
Sample type: Fish - fillet
Sample amount: 20,35 g (wet sample)
Concentration units: pg/g
Data files: DE608011-DE623011

Kjeller, 14.03.97

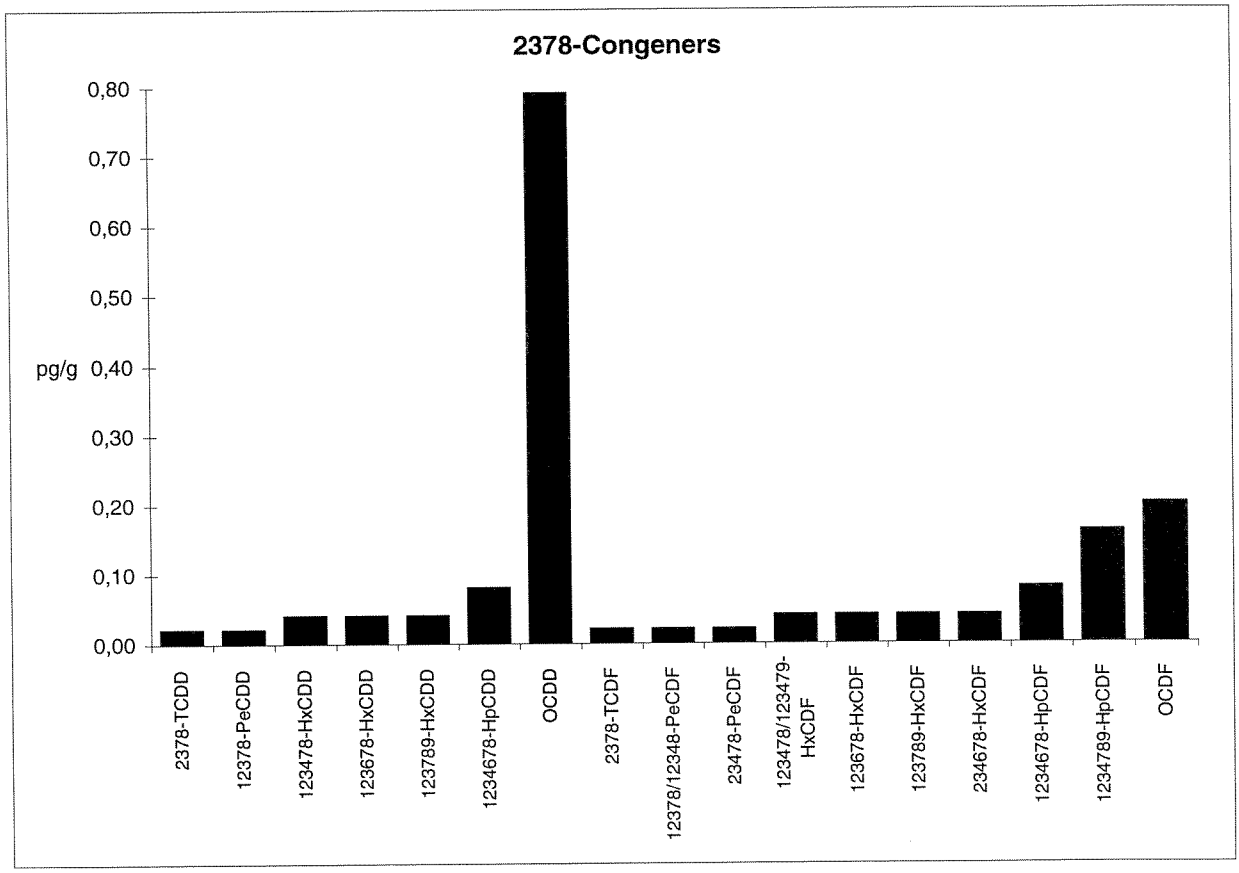
Compound	Concentration pg/g	Recovery %	TE (nordic) pg/g	i-TE pg/g
2378-TCDD	< 0,02	49	0,02	
SUM TCDD	**0,15**			
12378-PeCDD	< 0,02	52	0,01	
SUM PeCDD				
123478-HxCDD	< 0,04		0,00	
123678-HxCDD	< 0,04	52	0,00	
123789-HxCDD	< 0,04		0,00	
SUM HxCDD				
1234678-HpCDD	< 0,08	56	0,00	
SUM HpCDD				
OCDD	0,79	56	0,00	
SUM PCDD	**0,94**		**0,04**	
2378-TCDF	< 0,02	52	0,00	
SUM TCDF	**0,06**			
12378/12348-PeCDF	< 0,02		0,00	0,00
23478-PeCDF	< 0,02	58	0,01	
SUM PeCDF				
123478/123479-HxCDF	< 0,04	49	0,00	
123678-HxCDF	< 0,04		0,00	
123789-HxCDF	< 0,04		0,00	
234678-HxCDF	< 0,04		0,00	
SUM HxCDF				
1234678-HpCDF	< 0,08	56	0,00	
1234789-HpCDF	< 0,16		0,00	
SUM HpCDF				
OCDF	< 0,20	54	0,00	
SUM PCDF	**0,26**		**0,03**	**0,03**
SUM PCDD/PCDF	**1,20**		**0,07**	**0,08**

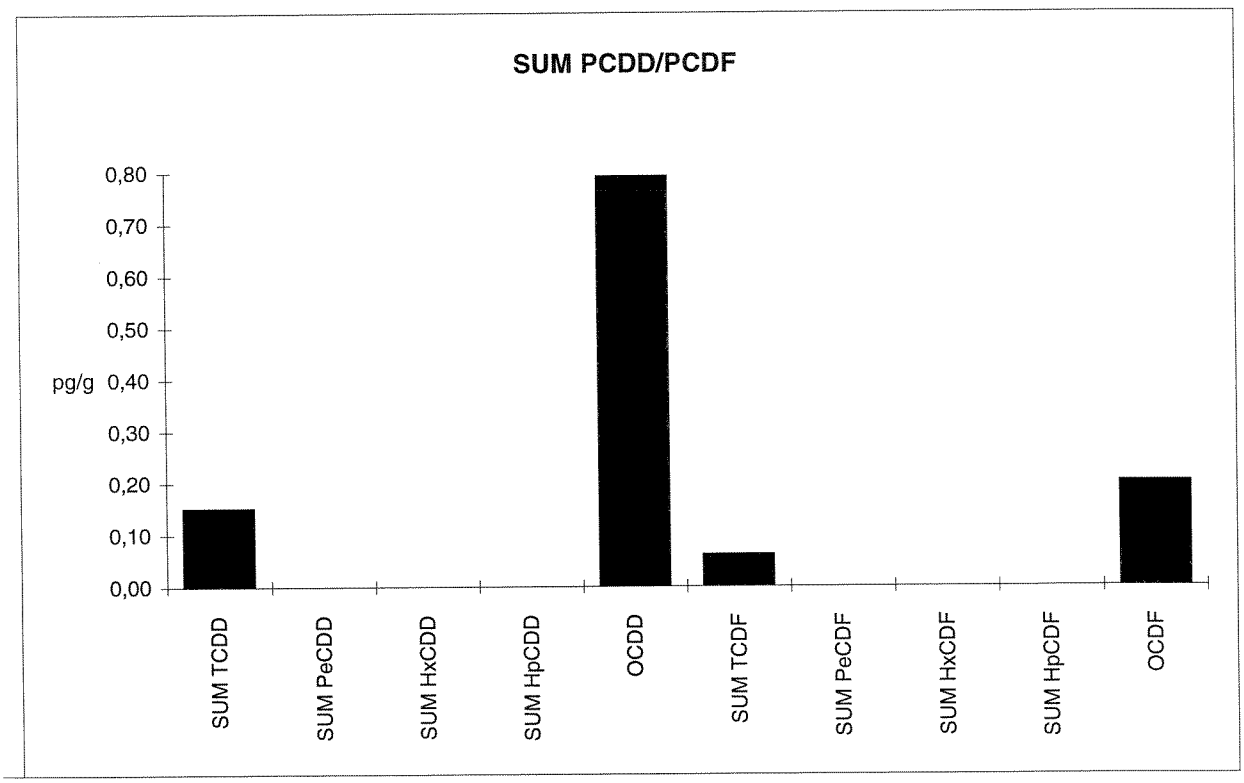
TE (nordic): 2378-TCDD toxicity equivalents according to the nordic model
i-TE: 2378-TCDD toxicity equivalents according to the international model
<: Lower than detection limit at signal-to-noise 3 to 1
(i): Isotope ratio deviates more than 20 % from theoretical value.
This may be due to instrumental noise or/and chemical interference

Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/697

Kjeller, 14.03.97





Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/698
Customer: NIVA
Customers sample ID: Khe Nghi - Vietnam
: Fish - fillet
Sample type: Fish - fillet
Sample amount: 20,4 g (wet sample)
Concentration units: pg/g
Data files: DE609011-DE624011

Kjeller, 14.03.97

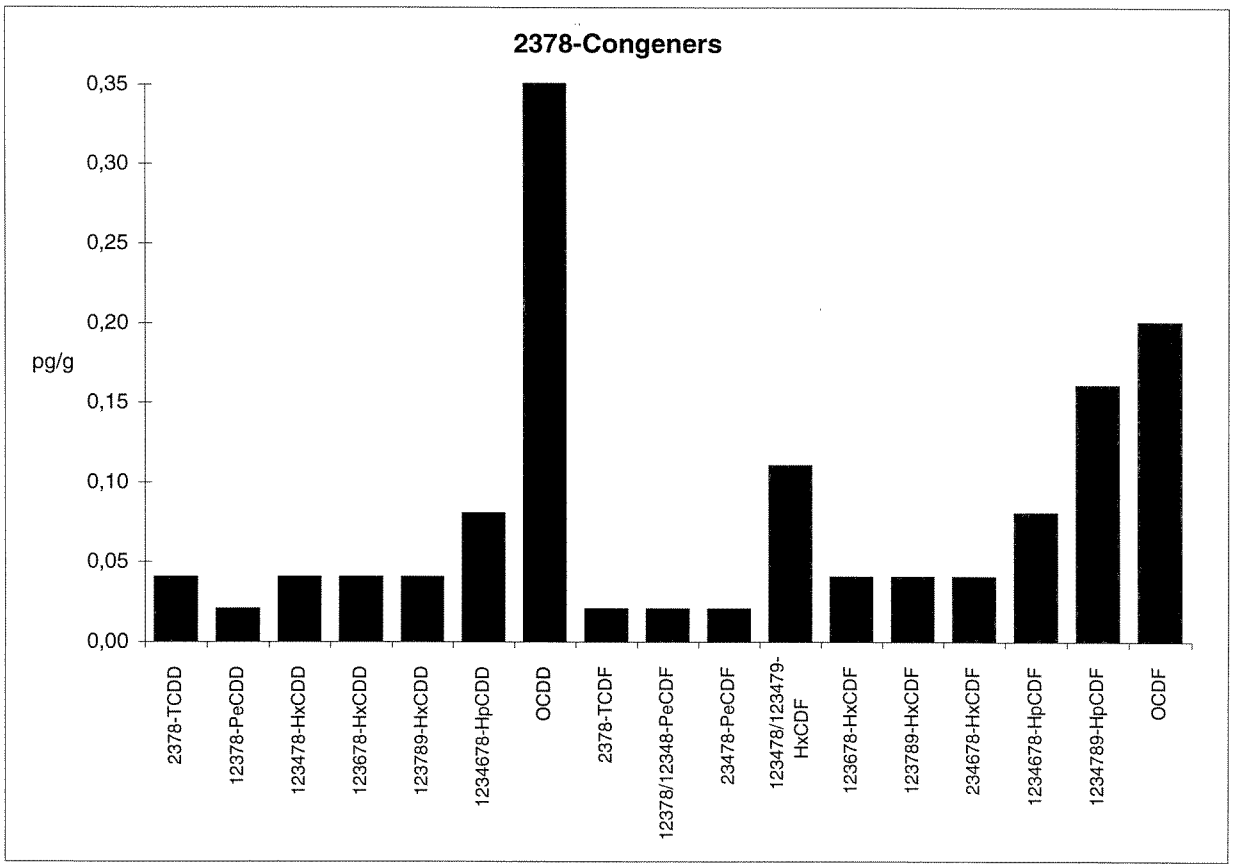
Compound	Concentration pg/g		Recovery %	TE (nordic) pg/g	i-TE pg/g
2378-TCDD	0,04	(i)	56	0,04	
SUM TCDD	**0,24**				
12378-PeCDD	< 0,02		64	0,01	
SUM PeCDD					
123478-HxCDD	< 0,04			0,00	
123678-HxCDD	< 0,04		72	0,00	
123789-HxCDD	< 0,04			0,00	
SUM HxCDD					
1234678-HpCDD	< 0,08		71	0,00	
SUM HpCDD					
OCDD	0,35		65	0,00	
SUM PCDD	**0,59**			**0,06**	
2378-TCDF	< 0,02		62	0,00	
SUM TCDF					
12378/12348-PeCDF	< 0,02			0,00	0,00
23478-PeCDF	< 0,02		66	0,01	
SUM PeCDF					
123478/123479-HxCDF	0,11	(i)	65	0,01	
123678-HxCDF	< 0,04			0,00	
123789-HxCDF	< 0,04			0,00	
234678-HxCDF	< 0,04			0,00	
SUM HxCDF	**0,11**				
1234678-HpCDF	< 0,08		70	0,00	
1234789-HpCDF	< 0,16			0,00	
SUM HpCDF					
OCDF	< 0,20		62	0,00	
SUM PCDF	**0,31**			**0,04**	**0,04**
SUM PCDD/PCDF	**0,90**			**0,10**	**0,10**

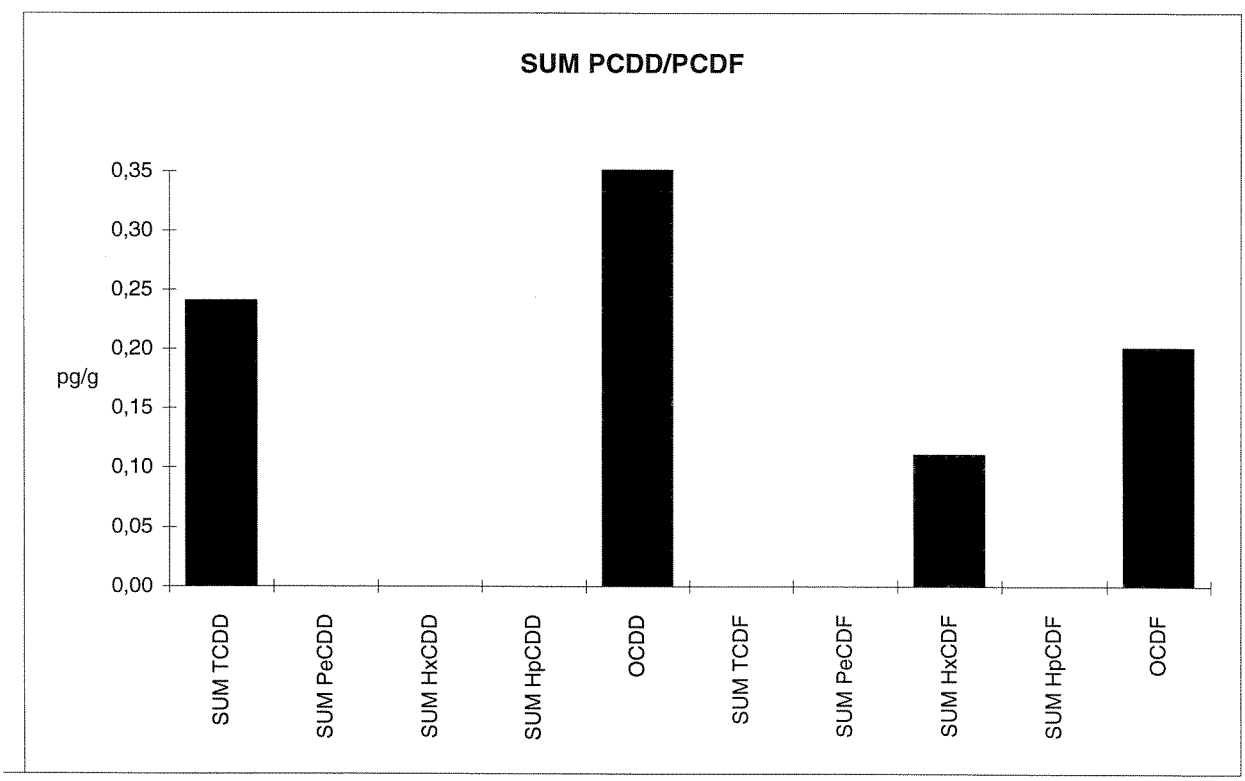
TE (nordic): 2378-TCDD toxicity equivalents according to the nordic model
i-TE: 2378-TCDD toxicity equivalents according to the international model
<: Lower than detection limit at signal-to-noise 3 to 1
(i): Isotope ratio deviates more than 20 % from theoretical value.
This may be due to instrumental noise or/and chemical interference

Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/698

Kjeller, 14.03.97





Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/699
Customer: NIVA
Customers sample ID: 1.Rao Quan - Vietnam
: Sediment
Sample type: Sediment
Sample amount: 15 g (dry sample)
Concentration units: pg/g
Data files: DE610011-DE625011

Kjeller, 14.03.97

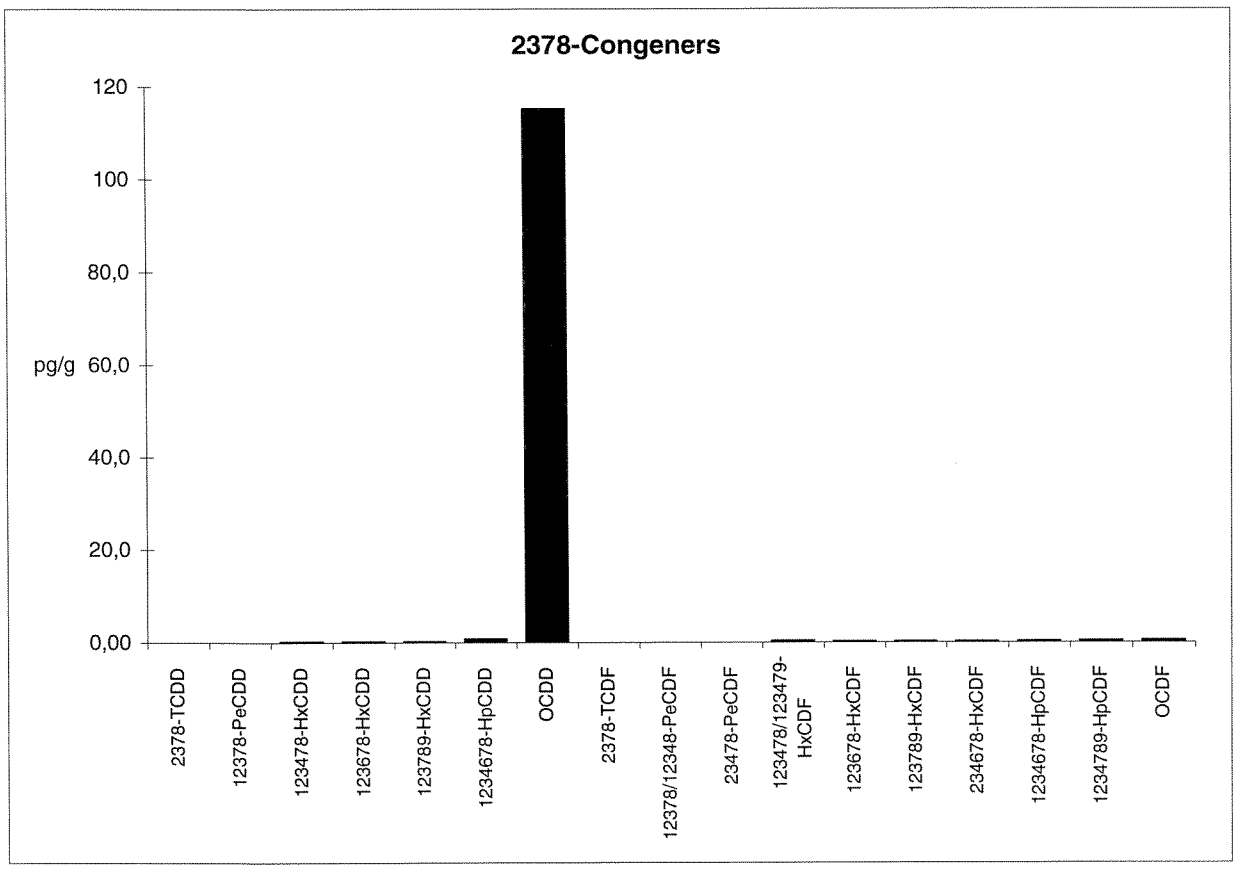
Compound	Concentration pg/g		Recovery %	TE (nordic) pg/g	i-TE pg/g
2378-TCDD	< 0,03		53	0,03	
SUM TCDD					
12378-PeCDD	< 0,03		64	0,02	
SUM PeCDD					
123478-HxCDD	< 0,08			0,01	
123678-HxCDD	< 0,08		69	0,01	
123789-HxCDD	< 0,08			0,01	
SUM HxCDD					
1234678-HpCDD	0,61	(i)	69	0,01	
SUM HpCDD	**1,10**				
OCDD	115		69	0,12	
SUM PCDD	**116**			**0,19**	
2378-TCDF	< 0,03		57	0,00	
SUM TCDF	**0,13**				
12378/12348-PeCDF	< 0,03			0,00	0,00
23478-PeCDF	< 0,03		68	0,02	
SUM PeCDF					
123478/123479-HxCDF	0,18	(i)	60	0,02	
123678-HxCDF	< 0,08			0,01	
123789-HxCDF	< 0,08			0,01	
234678-HxCDF	< 0,08			0,01	
SUM HxCDF	**0,18**				
1234678-HpCDF	< 0,12		71	0,00	
1234789-HpCDF	< 0,20			0,00	
SUM HpCDF					
OCDF	< 0,35		57	0,00	
SUM PCDF	**0,66**			**0,06**	**0,07**
SUM PCDD/PCDF	**117**			**0,25**	**0,26**

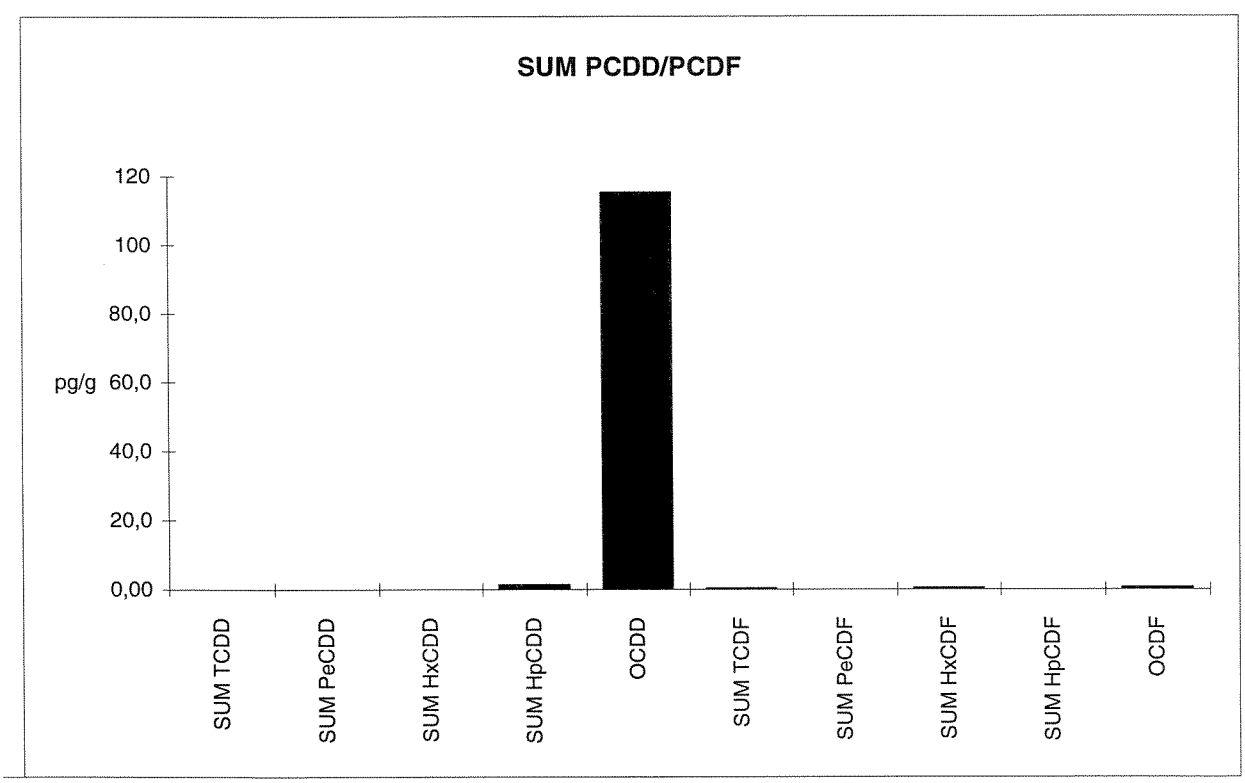
TE (nordic): 2378-TCDD toxicity equivalents according to the nordic model
i-TE: 2378-TCDD toxicity equivalents according to the international model
<: Lower than detection limit at signal-to-noise 3 to 1
(i): Isotope ratio deviates more than 20 % from theoretical value.
This may be due to instrumental noise or/and chemical interference

Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/699

Kjeller, 14.03.97





Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/700
Customer: NIVA
Customers sample ID: 2.Khe Nghi - Vietnam
: Sediment
Sample type: Sediment
Sample amount: 15 g (dry sample)
Concentration units: pg/g
Data files: DE743041

Kjeller, 14.03.97

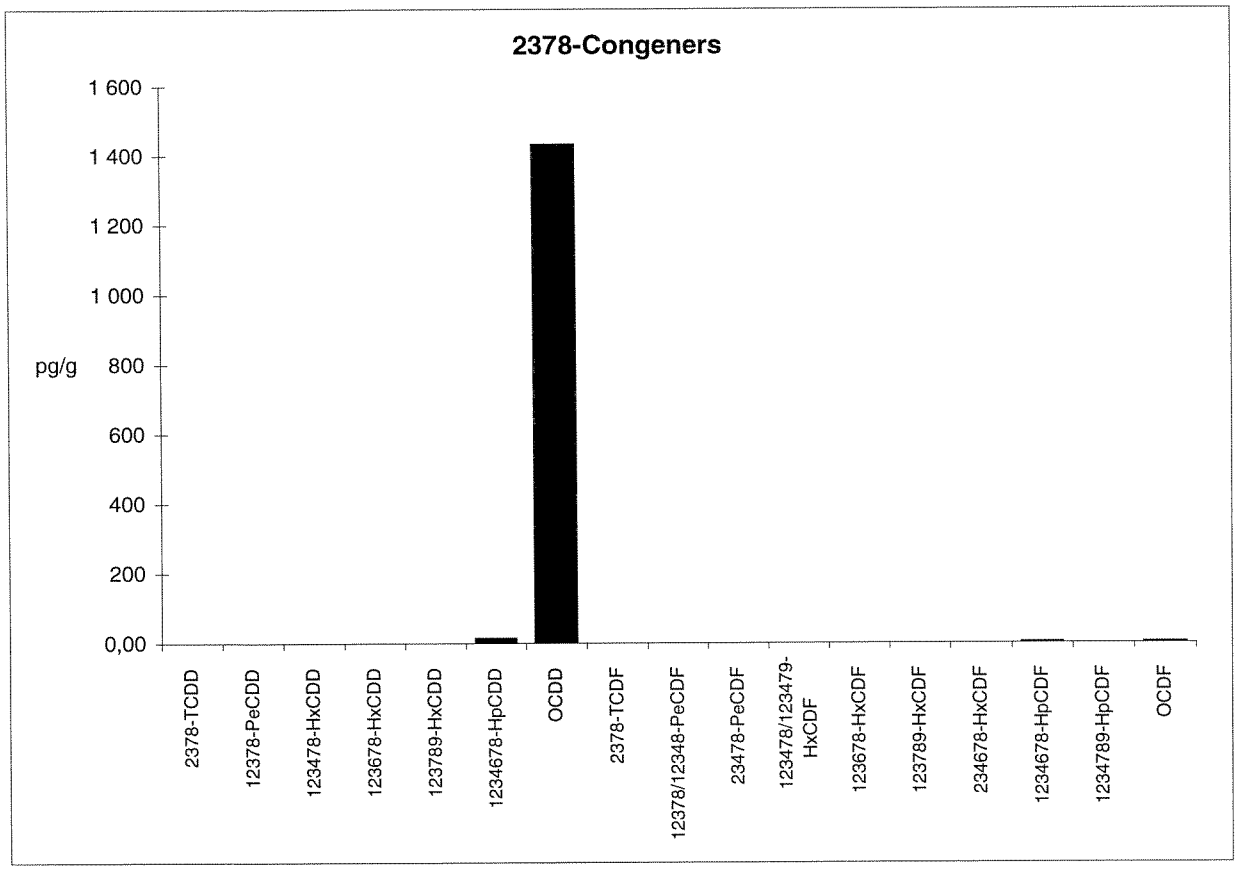
Compound		Concentration pg/g		Recovery %	TE (nordic) pg/g	i-TE pg/g
2378-TCDD		0,23	(i)	*	0,23	
SUM TCDD		**0,93**				
12378-PeCDD	<	0,03		*	0,02	
SUM PeCDD						
123478-HxCDD	<	0,08			0,01	
123678-HxCDD	<	0,08		*	0,01	
123789-HxCDD	<	0,08			0,01	
SUM HxCDD		**3,64**				
1234678-HpCDD		11,6		*	0,12	
SUM HpCDD		**30,3**				
OCDD		1 429		*	1,43	
SUM PCDD		**1 464**			**1,81**	
2378-TCDF		0,19		*	0,02	
SUM TCDF		**0,19**				
12378/12348-PeCDF	<	0,03			0,00	0,00
23478-PeCDF	<	0,03		*	0,02	
SUM PeCDF						
123478/123479-HxCDF	<	0,08		*	0,01	
123678-HxCDF	<	0,08			0,01	
123789-HxCDF	<	0,08			0,01	
234678-HxCDF	<	0,08			0,01	
SUM HxCDF						
1234678-HpCDF		0,48		*	0,00	
1234789-HpCDF	<	0,30			0,00	
SUM HpCDF		**0,48**				
OCDF		0,95		45	0,00	
SUM PCDF		**1,62**			**0,08**	**0,08**
SUM PCDD/PCDF		**1 465**			**1,89**	**1,89**

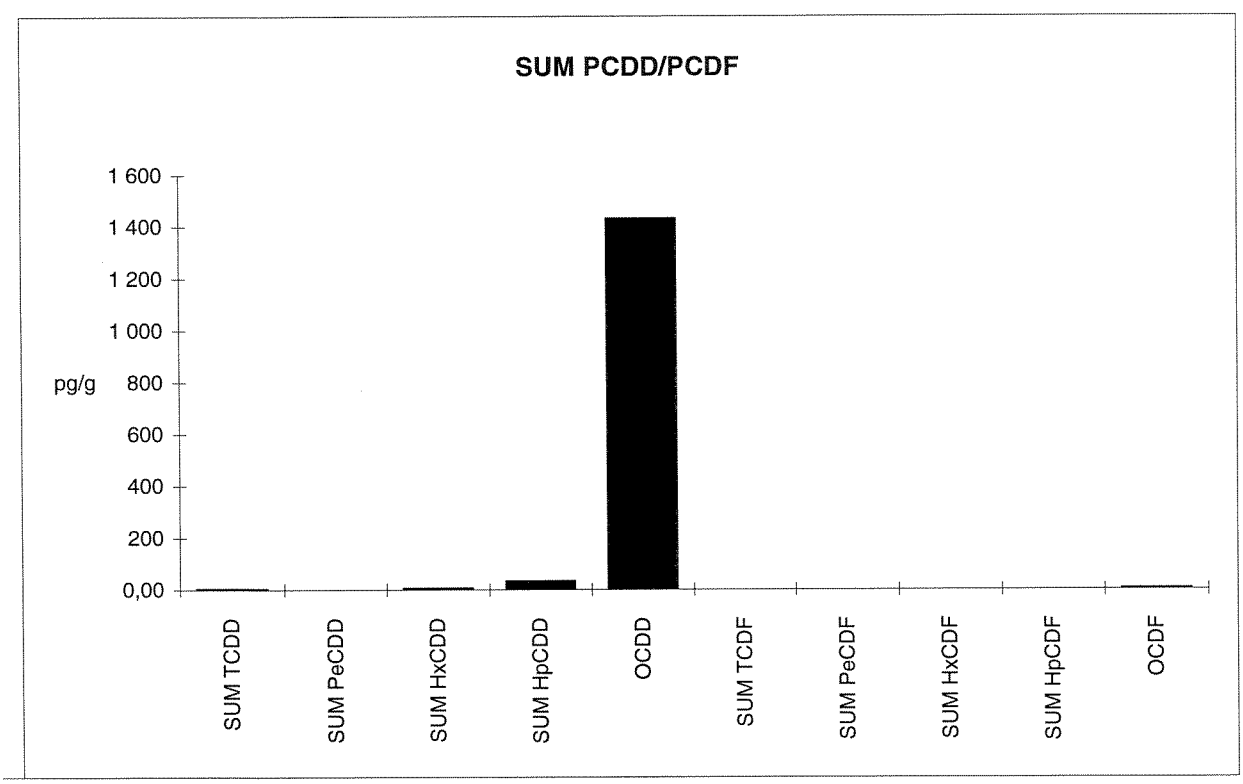
TE (nordic): 2378-TCDD toxicity equivalents according to the nordic model
i-TE: 2378-TCDD toxicity equivalents according to the international model
<: Lower than detection limit at signal-to-noise 3 to 1
(i): Isotope ratio deviates more than 20 % from theoretical value.
This may be due to instrumental noise or/and chemical interference

Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/700

Kjeller, 14.03.97





Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/701
Customer: NIVA
Customers sample ID: From rice paddy
: Sediment
Sample type: Sediment
Sample amount: 15 g
Concentration units: pg/g
Data files: DE612011-DE627011

Kjeller, 14.03.97

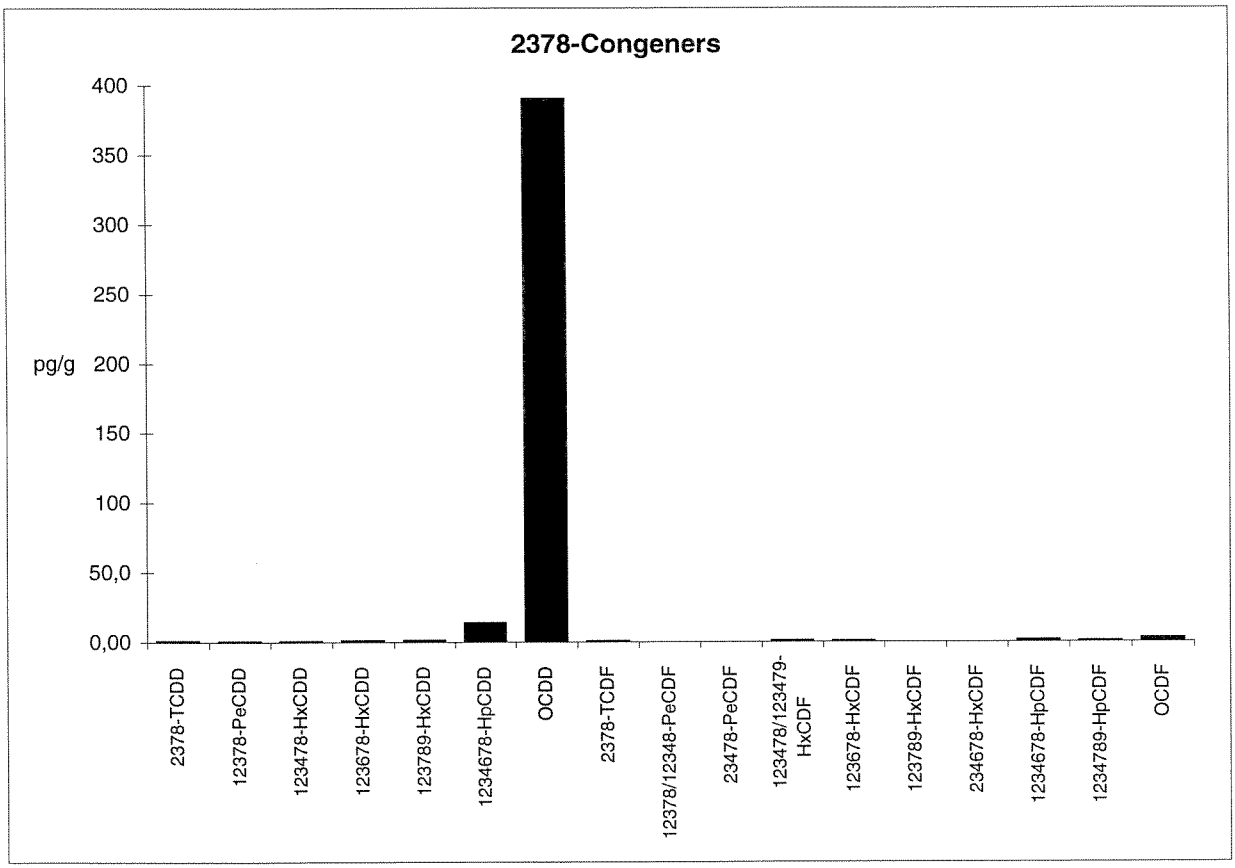
Compound	Concentration pg/g		Recovery %	TE (nordic) pg/g	i-TE pg/g
2378-TCDD	0,49	(i)	76	0,49	
SUM TCDD	**0,49**				
12378-PeCDD	0,26	(i)	84	0,13	
SUM PeCDD	**0,97**				
123478-HxCDD	0,23			0,02	
123678-HxCDD	0,62		90	0,06	
123789-HxCDD	0,86			0,09	
SUM HxCDD	**9,27**				
1234678-HpCDD	13,4		91	0,13	
SUM HpCDD	**31,9**				
OCDD	390		96	0,39	
SUM PCDD	**433**			**1,32**	
2378-TCDF	0,25		76	0,03	
SUM TCDF	**1,93**				
12378/12348-PeCDF	< 0,03			0,00	0,00
23478-PeCDF	< 0,03		76	0,02	
SUM PeCDF	**0,83**				
123478/123479-HxCDF	0,41	(i)	85	0,04	
123678-HxCDF	0,24	(i)		0,02	
123789-HxCDF	< 0,03			0,00	
234678-HxCDF	< 0,03			0,00	
SUM HxCDF	**1,98**				
1234678-HpCDF	1,00		91	0,01	
1234789-HpCDF	< 0,20			0,00	
SUM HpCDF	**1,82**				
OCDF	2,31		91	0,00	
SUM PCDF	**8,87**			**0,13**	**0,13**
SUM PCDD/PCDF	**442**			**1,44**	**1,44**

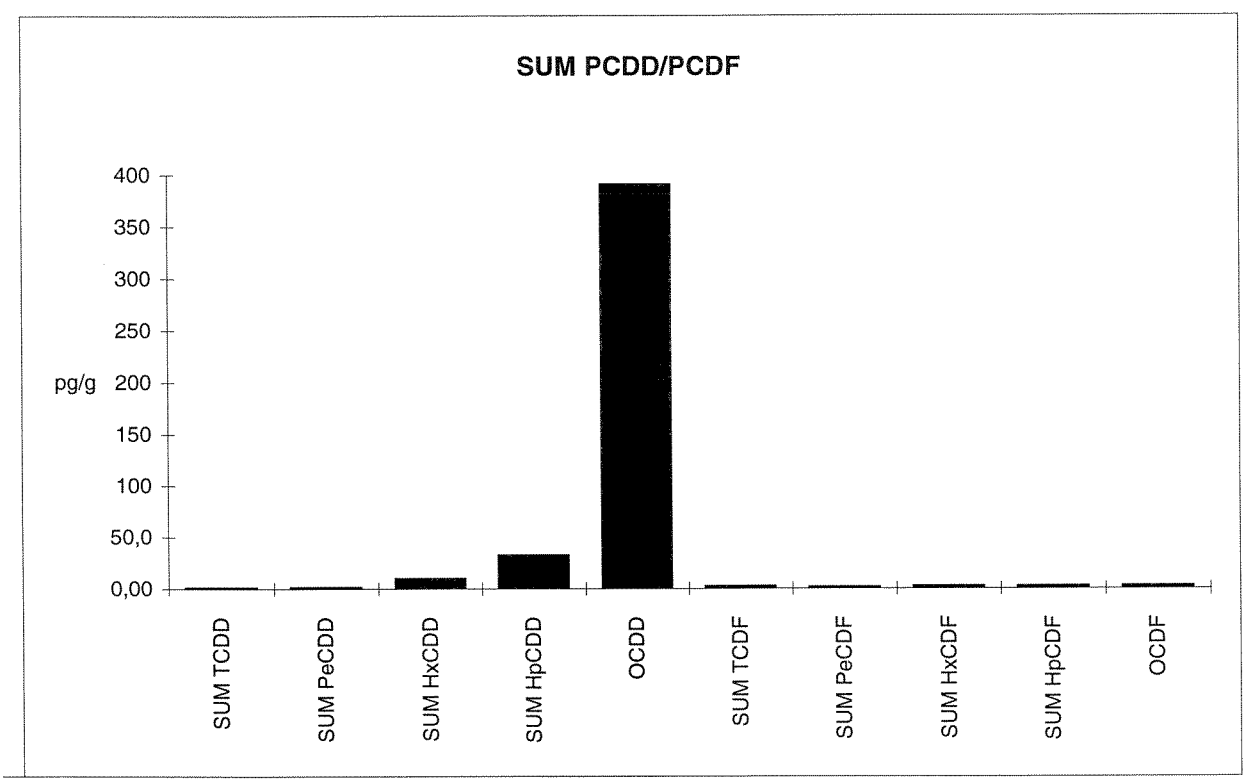
TE (nordic): 2378-TCDD toxicity equivalents according to the nordic model
i-TE: 2378-TCDD toxicity equivalents according to the international model
<: Lower than detection limit at signal-to-noise 3 to 1
(i): Isotope ratio deviates more than 20 % from theoretical value.
This may be due to instrumental noise or/and chemical interference

Results of PCDD/PCDF Analysis

Encl. to measuring report: O-296
NILU sample number: 96/701

Kjeller, 14.03.97





Short description of the method NILU-O-1

Sample preparation: Samples were spiked with ^{13}C-labelled 2,3,7,8-chloro substituted PCDD and PCDF congeners and soxhlet extracted with warm toluene.

Sample clean-up: Most of the sample matrix was removed with multi column chromatography on different types of silica gel and on activated charcoal. A final treatment was done on sulphuric acid coated silica and aluminium oxide. Just before quantification, the sample was spiked with a recovery control standard.

Quantification: The isomer identification and quantification was done with GC/MS. The separation of the PCDD and PCDF isomers was carried out on 30 m Rt_X-2330 fused silica column. The quantification of all 2,3,7,8-chloro substituted congeners and the determination of the sum of all isomers with the same degree of chlorination were done by high resolution mass spectrometry (res>10000) using electron impact ionisation. Two masses were monitored for each isomer group. The added ^{13}C-labelled isomers were used as internal standard for each group. Additionally, the recovery of the added internal standard compounds were determined.

Results: The concentration of the toxic 2,3,7,8-chloro substituted congeners were determined. For all these congeners, the 2,3,7,8-TCDD toxicity equivalent (TE) was calculated according to the international (NATO/CCMS) and the Nordic model. The TE is a measure for the total PCDD/PCDF toxicity of a sample, where the toxicity of all the 2,3,7,8-chloro congeners were compared to 2,3,7,8-TCDD. Furthermore, the total concentration (sum) of each group of isomers was determined.

Quality assurance: The following conditions must be fulfilled for an unequivocal identification and quantification of the PCDD and PCDF congeners:

1. The retention time must be in a window of +3 to 0 s compared to the corresponding ^{13}C-labelled isomer.
2. The isotope ratio of the two monitored isotopes must be within $\pm$20% of the theoretical value.
3. The signal/noise must be >3/1 for quantification.
4. The recovery of the added ^{13}C labelled internal standards must be within 40 to 120%.
5. Before each new series of samples the blank values of the complete clean-up and quantification procedures are determined. Clean-up of the sample only started when a sufficiently low blank value is obtained (not detectable or at least 10 times lower than the lowest expected results).

Table.... Filets from the most common fish (local name Ca' chay) caught in the two rivers were used for dioxin analysis

	Rao Quan		Khe Nghi	
	Weight (g)	Length(cm)	Weight(g)	Length(cm)
Single fish	10	10.2	38	15.2
"	8.5	8.6	28	13.9
"	11	10.9	13	11.4
"	7.5	9.7	16.5	12.9
"	9.2	10.2	9	11.3
"	13	11.2	14	11.7
"	9	9.9		
"	11.5	10.8		
"	25.5	14.2		
"	11	10.6		
"	5	8		
"	8	9.8		
Average	10.8	10.3	19.8	12.7

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