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Environmental monitoring in the vicinity of the Borssele nuclear power plant

Results in 2022

RIVM letter report 2023-0062
P.J.M. Kwakman

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Synopsis

Environmental monitoring in the vicinity of the Borssele nuclear power plant.

Results in 2022.

The ANVS tasked RIVM to yearly perform a check on the measurements which are carried out in the vicinity of the Borssele nuclear power plant by NRG. In 2022 various samples were also taken from grass, water, air dust, sediment and sea weed. The analytical results indicate that no radiological contamination as a result of business operations from the nuclear power plant can be found.

In most samples RIVM reports no activity, or a very low amount of natural activity, or in a sand sample a negligible activity of ^{137}Cs. The latter is a known surface contamination of ^{137}Cs in the Netherlands [7] and originates most likely from the Chernobyl accident.

In July 2022, all gross-bèta data from RIVM in river Scheldt water and suspended solids were in poor agreement with the results from NRG, possibly due to different measurement techniques.

In 2022, a low amount of tritium is found in water from the river Scheldt which is comparable to the amount found in previous years. Due to the upstream location of the Doel nuclear power plant in Belgium, the origin of this trace activity of tritium is hard to determine.

Commissioned by the NPP Borssele, the Nuclear Research and Consultancy Group (NRG) carries out monthly sampling of water, air dust, sediment, seaweed, and yearly sampling of sand. NRG analyzed these samples for gamma-emitters, gross alpha and gross beta activity, and the water sample for ^{3}H. Sampling air dust is not part of the control programme of RIVM.

Keywords: nuclear power plant Borssele, environment, radioactivity, measurements

Publiekssamenvatting

Milieumetingen in de omgeving van kerncentrale Borssele.

Resultaten in 2022

Het RIVM controleert elk jaar de metingen die de kerncentrale Borssele (KCB) in de directe omgeving van de centrale laat uitvoeren. Hiervoor zijn de monsters geanalyseerd die in 2022 zijn genomen van gras, water, luchtstof, sediment en zeewier. Er is geen radioactiviteit gevonden als gevolg van de bedrijfsvoering van de kerncentrale.

In de meeste gevallen vindt het RIVM geen radioactiviteit of een lage hoeveelheid van natuurlijke activiteit. Of het vindt sporen van cesium-137 in een grondmonster. Dit is een bekende besmetting en komt hoogstwaarschijnlijk van het kernongeval bij Chernobyl in 1986.

In juli 2022 was er een matige overeenstemming tussen de RIVM- en NRG-data voor totaal-bèta in water van de Westerschelde en zwevend slib. Dit heeft te maken met verschillen in de methode waarmee de waarden worden bepaald.

Het RIVM heeft in 2022 in enkele watermonsters van de Westerschelde een zeer lage hoeveelheid van tritium (^{3}H) aangetroffen. Het is niet bekend waar dat vandaan komt omdat tritium van kerncentrale Doel eveneens langs KCB stroomt

Sinds de jaren negentig van de vorige eeuw laat de KCB de monsters elke maand uitvoeren door de Nuclear Research and Consultancy Group (NRG). NRG neemt elk jaar ook een grondmonster. NRG analyseert deze monsters op gammastralers, totaal-alfa en totaal-bèta activiteit, en tritium in het watermonster. De bemonstering van luchtstof behoort niet tot het controleprogramma van RIVM. Het RIVM controleert de metingen in opdracht van de Autoriteit Nucleaire Veiligheid en Stralingsbescherming (ANVS).

Kernwoorden: kerncentrale Borssele, NRG, milieumetingen, radioactiviteit

Contents

Kwaliteitssysteem

Het Centrum Veiligheid van het Rijksinstituut voor Volksgezondheid en Milieu (RIVM/VLH) is voor een aantal verrichtingen geaccrediteerd door de RvA volgens NEN-EN-ISO-17025 (registratienummer L153). Deze verrichtingen hebben betrekking op metingen die worden uitgevoerd in het kader van het toezicht op nucleaire installaties (ANVS), het Nationaal Meetnet Radioactiviteit en milieu-monitoring ter uitvoering van het EURATOM Verdrag.

De metingen en analyses zoals beschreven in dit rapport wijken af van deze standaard verrichtingen en vallen daarom niet onder deze accreditatie. Waar mogelijk is echter in overeenstemming met de standaard procedures ter kwaliteitsborging gewerkt, in het bijzonder ten aanzien van validatie van de kwantitatieve aspecten

Summary

Environmental monitoring in the vicinity of the Borssele nuclear power plant.
Results in 2022.

Regularly RIVM performs a check on parts of the measurements that were carried out in the vicinity of the Borssele nuclear power plant (NPP). The NPP assigned the Nuclear Research and Consultancy Group (NRG) to carry out monthly sampling of water, air dust, sediment, seaweed, and yearly sampling of sand. NRG analyzed these samples for gamma-emitters, ^{3}H, gross alpha and gross beta activity.

In most samples RIVM reports no activity, or a very low amount of natural activity, or in a sand sample a negligible activity of ^{137}Cs. The latter is a known surface contamination of ^{137}Cs in the Netherlands [7] and originates most likely from the Chernobyl accident.

In July 2022, all gross-bèta data from RIVM in river Scheldt water and suspended solids were in poor agreement with the results from NRG, possibly due to different measurement techniques.

In 2022, a low amount of tritium is found in water from the river Scheldt which is comparable to the amount found in previous years. Due to the upstream location of the Doel nuclear power plant in Belgium, the origin of this trace activity of tritium is hard to determine.

Commissioned by the NPP Borssele, NRG carries out monthly sampling of water, air dust, sediment, seaweed, and yearly sampling of sand. NRG analyzed these samples for gamma-emitters, gross alpha and gross beta activity, and the water sample for ^{3}H. Sampling air dust is not part of the control programme of RIVM.

1 Introduction

The Dutch nuclear power plant at Borssele is operated by the Electriciteits Productiemaatschappij Zuid-Nederland (EPZ). Where in this report "EPZ" is mentioned, it is in fact the nuclear power plant Borssele.

1.1 Brief history

EPZ has an obligation to carry out an environmental monitoring programme in the vicinity of the Borssele NPP. This environmental programme was described in 1994 in ref. [1] by the former contractor KEMA (now NRG, Nuclear Research and consultancy Group). The programme consists of monthly sampling of air dust, sediment, grass, water, suspended solids and seaweed; soil near the coolingwater outlet is sampled once a year.
The measurements results are reported by EPZ and parts of the data are published in the yearly RIVM report on Environmental Radioactivity in the Netherlands [2].

1.2 Goal – Independent verification of environmental monitoring

In 2014, a team of the Integrated Regulatory Review Service (IRRS) visited the Netherlands on request of the Dutch Government. The team members reviewed the regulatory framework with regard to the Dutch nuclear and radiological facilities and activities.
In the IRRS report [3], one of the recommendations (R25) deals with an independent verification of the environmental monitoring reported by the regulated facilities. The verification was described in detail in the 2018 report [4] in which all samples were taken by NRG and analyzed by both NRG and RIVM . In this report over the period 2022 RIVM carried out sampling independent of the sampling campaign of NRG.

1.3 Evaluation of the environmental monitoring programme

In 2019, NPP Borssele tasked NRG to perform an internal review of the environmental monitoring programme around the nuclear power plant Borssele [5]. The environmental compartments air, sand, surface water and river water, and direct gamma radiation were evaluated. Especially the amount of samples taken in those compartments and the applied measurements techniques were assessed. Next, the environmental programmes of Belgium and Finland were compared with the environmental programme carried out around NPP Borssele.

In conclusion, there was no need to change this programme. Only one minor improvement was suggested by NRG. This improvement concerned a system for aerosol sampling.

2 Sampling Programme by EPZ and RIVM

2.1 The sampling programme by EPZ, carried out by contractor NRG.

The sampling programme, which is carried out by the Nuclear Research and Consultancy Group (NRG), Petten, was described in an earlier report [1, 4]. This programme has been routinely carried out by NRG with a monthly frequency for a large number of years.
Samples are taken in order to monitor radionuclides in air dust, grass, sand, water, suspended solids, seaweed and sediment [1]. The monitoring programme for environmental samples is outlined in Table 1 and Figure 1.

Table 1 Monitoring programme for environmental samples taken by contractor NRG near the Borssele nuclear power plant in 2022

Matrix	Location (Fig 2)	Parameter	Monitoring frequency (per year)
Air dust	21, 22, 23, 27 and 29	gross α, gross β	12
		γ-emitters (1)	12 (2)
Grass	21, 22, 23, 27 and 29	γ-emitters (3)	12 (2)
Sand	O1, O2, O3 and O4 (4)	γ-emitters (5)	1
Water	1, 2, 3 and 4	residual β, ^{3}H	12
Suspended solids	1, 2, 3 and 4	gross β	12
Seaweed	1, 2, 3 and 4	γ-emitters (3)	12 (2)
Sediment	1, 2, 3 and 4	γ-emitters (3)	12 (2)

The location numbers correspond to the location numbers given in Figure 2.
(1) γ-spectroscopic analysis of specific γ-emitting radionuclides: ^{60}Co, ^{137}Cs, naturally occurring radionuclides and elemental and organically bound ^{131}I.
(2) Analysis was performed on a combined sample of monthly samples taken from all four or five locations.
(3) γ-spectroscopic analysis of specific γ-emitting radionuclides: ^{60}Co, ^{131}I and ^{137}Cs.
(4) The four locations where samples were taken near the outlet are not shown in Figure 2.
(5) γ-spectroscopic analysis of specific γ-emitting radionuclides: ^{54}Mn, ^{60}Co, ^{134}Cs and ^{137}Cs.

The map in Fig 1 shows the vicinity and larger area around the Borssele nuclear power plant. The NPP is situated in the red circle in the centre of the map. The circles represent distances of 2, 4, 6, 8 and 10 km.
The Westerscheldt is basically the estuary of the river Scheldt ("Schelde" in Dutch). Just some 30 km upstream, in Belgium, the Doel nuclear power plant is situated. This NPP, containing 4 reactors of which one is not in operation, also discharges waste water to the river Scheldt.

Figuur 1 Surroundings of the Borssele nuclear power plant (in red circle). The numbers on the map refer to sampling locations.

2.2 Sampling programme and analyses by RIVM

Starting from 2018 the ANVS tasked RIVM carry out a check on the monitoring campaign of NRG. In the years 2018 – 2020 NRG carried out monthly sampling. Parts of samples of one selected month were transferred to the RIVM for analysis. Due to the Covid-19 pandemic sampling was not carried out in 2021.
In 2022 RIVM carried out an independent sampling procedure on samples of one month. The analyses were performed on a selection of samples taken on July 5th, 2022, see Table 1. The only exception is air dust which is not sampled by RIVM. It is not practical and very costly to operate duplicate air sampling equipment.

In Table 2, an overview is given on sample handling and the proposed analyses.

Table 2 Overview of analyses by RIVM in 2022

Sample matrix	Subsamples*	Parameter
Grass	1 bag of grass.	Gamma spec
Seaweed	300-400 g seaweed	Gamma spec
Sediment	Half of sample	Gamma spec
Sand	Sample of ~0,5 kg	Gamma spec
Water from river Scheldt	1 L of filtrate	Gross alpha/beta, ^{3}H (LSC)
Suspended solids	Precipitate in filtrate after NH_4OH addition	Gross alpha/beta

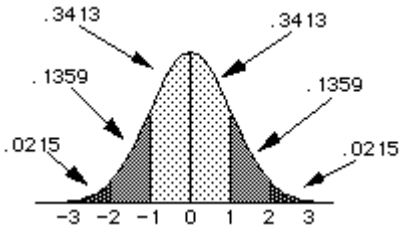
* Samples of grass and seaweed are stored in a freezer until sample treatment.

2.3 Comparison of RIVM and EPZ data

Where applicable, a comparison of RIVM and NRG data is carried out based on measurement data with uncertainties.
The comparison of the data from NRG ($x_{NRG} \pm u_{NRG}$) and from RIVM ($x_{RIVM} \pm u_{RIVM}$) is expressed as the difference Δ (= x_{NRG} - x_{RIVM}) in relation to the uncertainty $U\Delta$ in this difference; $U\Delta = \sqrt{(u_{NRG}^2 + u_{RIVM}^2)}$. This way of comparing is similar to a usual z-test in intercomparison exercises.

The agreement between the measurement data from RIVM and NRG is arbitrarily categorized as A1, A2, B and C. See Figure 2.

A1:	$\lvert\Delta\rvert \leq U\Delta$	probability ~68%, or 2 out of 3
A2:	$U\Delta < \lvert\Delta\rvert \leq 2\,U\Delta$	probability ~27%, or 1 out of 4
B:	$2\,U\Delta < \lvert\Delta\rvert \leq 3\,U\Delta$	probability ~4,3%, or 1 out of 20
C:	$3\,U\Delta < \lvert\Delta\rvert$	probability ~0,26%, or 1 out of 400



Figuur 2 Schematic presentation of a normal (Gauss) distribution

3 RIVM results and discussion

The NRG data of sampling period 2022 were reported to EPZ in February 2023 [6]. See Table 3 for a summary of the results relevant for this period, with the exception of air dust monitoring.

3.1 Overview of analytical data by RIVM and NRG in 2022

In the Table below, a summary of all analytical data of the RIVM measurements on the samples of July 2022, and sand samples from May 2022, are given next to the NRG data on the same samples. In Annex A, all data are presented in separate tables A1 – A7.

Table 3 Summary of RIVM and NRG measurement results; samples from July 5, 2022, and the yearly sand sample from 16 May 2022.

Matrix	Parameter	Number of Locations	Values RIVM; July 2022	Minimum and maximum values NRG [6]; July 2022
Grass	^{60}Co	5 (1)	< 9	< 1
(Bq·kg^{-1})	^{131}I	5 (1)	< 9	< 1
	^{137}Cs	5 (1)	< 9	< 1
Sand	^{54}Mn	4	< 0.7	< 0.2
(Bq·kg^{-1})	^{60}Co	4	< 0.7	< 0.2
16 May '22	^{134}Cs	4	< 0.7	< 0.2
	^{137}Cs	4	< 0.4 – 1.2 ± 0.2	0.39 ± 0.04 - 1.36 ± 0.11
Water	Gross β(5)	4	0.18 – 0.22	0.02 – 0.07
(kBq·m^{-3})	^{3}H	4	6.2 – 7.2	< 3
Suspended solids	Gross β	4	< 1.8 < 0.4	4.3 – 7 1.2 – 2.2
(kBq·kg^{-1})				
Seaweed	^{60}Co	4 (1)	< 4	< 1
(Bq·kg^{-1})	^{131}I	4 (1)	< 6	< 1
	^{137}Cs	4 (1)	< 4	< 1
Sediment	^{54}Mn	4 (2)	< 0.5	
	^{60}Co	4 (2)	< 0.5	< 0.2
(Bq·kg^{-1})	^{131}I	4 (2)	< 0.7	< 0.3
	^{137}Cs	4 (2)	0.60 ± 0.12	0.91 ± 0.14

(1) Analysis was performed by NRG and RIVM on a mix of samples taken in one month on 4-5 locations.
(2) Analysis was performed by NRG on a mix of the four or five samples taken in the same month. RIVM analyzed all individual samples. A given range represents values of individual samples; see Annex A for individual data.

3.2 Discussion of the results

In general, the RIVM and NRG data in Table 3 (2022) are in relatively good agreement. Most activity concentrations are below the detection limit or very low, mostly due to natural radioactivity or ^{137}Cs originating from the Chernobyl accident.

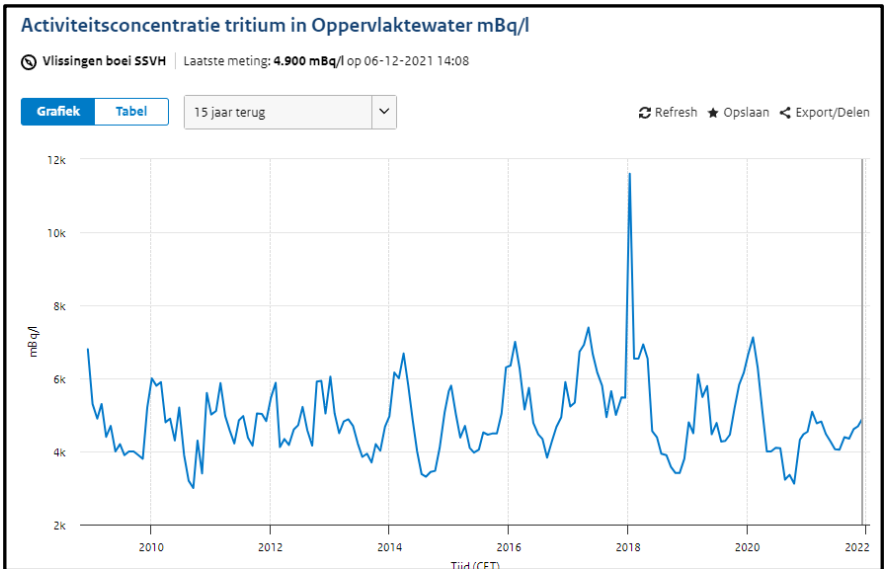
Grass and seaweed
Both RIVM and NRG did not find any artificial radionuclides, such as ^{60}Co, ^{131}I and ^{137}Cs, in monthly grass and seaweed samples.

Sand and dried sediments
Very low levels of ^{137}Cs were found in sand and dried sediments. This is not unusual in Dutch soil as a result of the Chernobyl accident [7]. In sand the agreement between the RIVM and NRG results is acceptable (A1, 2 x B).

Water from river Scheldt
For gross beta activity in water from river Scheldt, the RIVM results (0.18 – 0.22 kBq.m^{-3}) were about a factor of 3-8 higher than the NRG results. This may have to do with the different sample treatment and measuring techniques. RIVM uses a precipitation of a 10 ml subsample, NRG uses a larger volume and measures 10 times a planchet each with 250 mg.

Suspended solids samples from river Scheldt
RIVM did not find a gross beta activity in the suspended solid samples (< 1.8 kBq.kg^{-1}), where NRG reported gross beta activities between 1.2 - 7 kBq.kg^{-1}. These results do not compare well and need further investigation by RIVM and NRG.

Tritium in water from river Scheldt
The exact origin of traces of ^{3}H in water from the Scheldt, sampled in 2022, cannot be determined from these measurements. ^{3}H may originate from discharges from NPP Borssele or from NPP Doel further upstream, just over the Belgian border. See also Figure 3 with tritium data at location Vlissingen Boei sampled by Rijkswaterstaat in the period 2008 – 2022.



Figuur 3 Activity concentration of tritium in surface water sampled at Vlissingen Boei (mBq.l^{-1}) from 2008 until 2022. Data from Rijkswaterstaat (waterinfo.rws.nl).

In 2002, the activity concentration of ^{3}H ranged from 4.3 – 5.0 Bq.l^{-1}. This is practically the same range as in the data found in samples from river Scheldt in Table 3.

4 Conclusions

The ANVS tasked RIVM to regularly perform a check on parts of the measurements which are carried out by the Nuclear Research and Consultancy Group (NRG) on samples taken in the vicinity of the Borssele nuclear power plant (NPP).
The NPP Borssele assigned NRG to carry out monthly sampling of water, air dust, sediment, seaweed, and yearly sampling of sand. All these samples were taken around the NPP Borssele on fixed locations as described in an environmental monitoring programme [1]. NRG analyzed these samples for gamma-emitters, gross alpha and gross beta activity, and the water sample for ^{3}H.
In 2022 various samples were also taken and analyzed by RIVM. The analytical results indicate that no radiological contamination as a result of business operations from the nuclear power plant can be found.

In 2022, The levels of radioactivity in grass, sand, and dried sediments for artificial radionuclides were very low and close to the detection limit or below. The data were consistent with data from NRG. Gross-bèta data from NRG and RIVM in river Scheldt water and suspended solids did not compare well, possibly due to different measurement techniques.

A low amount of tritium is found in water from the river Scheldt, but due to the upstream location of the Doel nuclear power plant in Belgium, the exact origin of this trace activity of tritium is hard to determine.

In general, the RIVM and NRG data are in relatively good agreement. In most samples, RIVM reports detection limits, a very low amount of natural activity, or in a sand sample a negligible activity of ^{137}Cs. This is a known surface contamination of about 90 – 100 $Bq.m^{-2}$ ^{137}Cs in the Netherlands [7] and originates most likely from the Chernobyl accident in 1986.

5 Annex A Data tables 2022

Table A1 Gamma activity in grass sampled on July 5 2022 (Bq.kg^{-1}).

Sample*	Nuclide	RIVM#	NRG#
Grass	^{60}Co	< 9	< 1
	^{137}Cs	< 9	< 1
	^{131}I	< 9	< 1

* The sampling locations are nr. 21, 22, 23, 27 and 29 (see Fig 2).
n.d. = not detected due to short half-life of I-131
# NRG and RIVM both analyzed a mix sample of all 5 sampling locations. For NRG data, see ref [6], Table 7 and 8.

Table A2 Gamma activity in sand sampled on 16 May 2022 (Bq.kg^{-1})

Sample location*	Nuclide	RIVM#		NRG#
1, 2, 3, 4	^{54}Mn	< 0.4 - < 0.7		< 0.1 - < 0.2
	^{60}Co	< 0.4 - < 0.7		< 0.1 - < 0.2
	^{134}Cs	< 0.5 - < 0.7		< 0.01 - < 0.2
	^{137}Cs	1.2 ± 0.2 (1)	A1	0.99 ± 0.08 (1)
		0.7 ± 0.1 (2)	B	0.42 ± 0.04 (2)
		0.9 ± 0.2 (3)	B	1.36 ± 0.11 (3)
		< 0.4 (4)		0.39 ± 0.04 (4)

* The sampling locations are shown in Fig 2. Values are minimum and maximum values
# For NRG data, see ref [6], Table 9.

Table A3 Gross beta activity in water from river Scheldt, sampled on July 5, 2022 (kBq.m^{-3})

NRG sample location nr	RIVM gross-β		NRG# gross-β
1 (West)	0.19 ± 0.04	C	0.029 ± 0.007
2 (Centr.)	0.22 ± 0.04	C	0.066 ± 0.009
3 (East)	0.18 ± 0.04	C	0.022 ± 0.007
4 (El.dijk)*	0.20 ± 0.04	C	0.045 ± 0.009

* El. Dijk = Ellewoutsdijk
# For NRG data, see ref [6], Table 10.

Table A4 Gross beta activity in suspended solids from river Scheldt water, sampled on July 5, 2022 (kBq.kg^{-1})

NRG sample location nr	RIVM gross-β	NRG# gross-β
1 (West)	< 0.8	4.3 ± 1.9
2 (Centr.)	< 1.8	7 ± 2
3 (East)	< 0.4	2.2 ± 0.5
4 (El.dijk)*	< 0.3	1.16 ± 0.09

* El. Dijk = Ellewoutsdijk
# For NRG data, see ref [6], Table 11 and 12.

Table A5 Tritium activity in water from river Scheldt water, sampled on July 5, 2022 (kBq.m^{-3})

NRG sample location nr	RIVM ^{3}H	NRG# ^{3}H
1 (West)	7.2 ± 1.5	< 3
2 (Centr.)	6.2 ± 1.5	< 3
3 (East)	6.2 ± 1.6	< 3
4 (El.dijk)*	6.2 ± 1.6	< 3

* El. Dijk = Ellewoutsdijk
# For NRG data, see ref [6], Table 13.

Table A6 Gamma activity in seaweed, sampled on July 5, 2022 (Bq.kg^{-1})

NRG sample mix (4 loc.)*	RIVM Bq.kg^{-1}	NRG# Bq.kg^{-1}
^{60}Co	< 4	< 1
^{137}Cs	< 4	< 1
^{131}I	< 6	< 1

* NRG and RIVM both analyzed a mix sample of all 4 sampling locations: West, Centrale, East, Ellewoutsdijk.
# For NRG data, see ref [6], Table 14.

Table A7 Gamma activity in dried sediments, sampled on July 5, 2022 (Bq.kg^{-1})

Samples	RIVM* (4 loc.)	NRG# (mix)
^{54}Mn	< 0.2 - < 0.5	
^{60}Co	< 0.4 - < 0.5	< 0.2
^{131}I	< 0.5 - < 0.7	< 0.3
^{134}Cs	< 0.3 - < 0.5	
^{137}Cs	< 0.2 – 0.60 ± 0.12	0.91 ± 0.14

* RIVM analyzed all 4 samples separately. The data shown are a 'min – max' range.
# NRG analyzed a mixed sample of all 4 samples. For NRG data, see ref [6], Table 15.

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