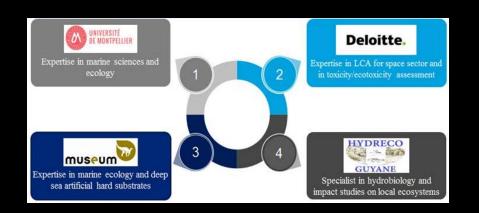


Functional Ecology to Reduce Launchers Impact on Deep Sea (ESA AO 1-8623/16/NL/KML)









Since 2012, the space sector initiated the Clean Space initiative to investigate Life Cycle of Europe's launch vehicles but also space missions. However, up to now ecotoxicological impacts on marine ecosystems of launching, and particularly, of launching residues were under investigated and oversimplified.

The strategic objectives of LAUNCHDESC are:

- To help ESA face the increasing concern of its customers, stakeholders and the general Public about the environmental impacts of space activities, with special focus on the ecotoxicity and human toxicity impacts of launcher stages falling in the ocean (Ariane 5 and Vega).
- To give ESA the possibility to progressively move toward eco-design by identifying key risk materials and suggesting design/process changes that could possibly reduce the environmental impacts of European launchers.

The approach is three-fold:

- 1. Characterisation of relevant Launcher materials
- 2. Marine ecosystems characterisation and preliminary environmental impacts
- 3. Further study to deepen understanding of environmental impact of disposed launchers















Main objectives:

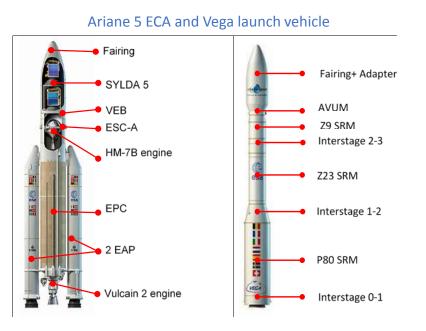
- Inventory of launching components and materials (metals, plastics, composite, and propellant fuels and residues) and their physical-chemical characteristics
- Marine ecosystems characterisation
- Behaviour and degradation of launcher materials in marine ecosystems
- List of potential ecotoxicological impacts on deep marine ecosystems of launcher components
- Preliminary environmental impacts
- Improvement of Life Cycle Impact Assessment (LCIA) models on marine ecotoxicity and human toxicity





Inventory of launcher components

- Data sources:
 - Ariane 5 and Vega LCA reports
 - Documentation from ESA
 - Literature review (internet search on chemistry websites, Material data sheets, Chemistry Handbook, etc.)
 - Assumptions, either on the mass and/or size of certain components, or on the type/composition of material used
- The inventory was built in several steps:
 - Breakdown of launchers in stages / elements of each stage / components of each element
 - Determination of mass and surface for each component
 - Determination of the composition of components
 - Decomposition in chemical elements for complex materials
 - Compilation of physical-chemical characteristics of each chemical element and raw material from different data sources
- Only aggregated data per stage of the launcher are presented here, without the full composition breakdown for each element



Inventory of launcher components

Gold <1			
GSM 55: Rubber EPDM + silica 2000-8000 <1 Hastelloy X 70-150 <1 Haynes 230 (Nickel alloy) 150-500 <1 Helium <1 <1 Hydrazine <1 <1 Hydrogen 500-1000 <1 roxyl-terminated polybutadiene 500-1000 70-150 Imide 10-70 <1 Incolloy A286 1-10 <1 Inconel 600 150-500 <1 Inconel 625 70-150 <1 Inconel 718 500-1000 <1 Iron powder <1 <1 <1 Iron powder <1 <1 <1 Isocyanates <1 <1 <1 Iron powder <1 <1 <1 Itiquid hydrogen LH2 150-500 <1 <1 Isocyanates <1 10070 <1 Itiquid hydrogen LH2 150-500 <1 <10 Itiquid oxygen LOx 10000-2000 <1 <10 <td>Gold</td> <td><1</td> <td><1</td>	Gold	<1	<1
Hastelloy X 70-150 <1 Haynes 230 (Nickel alloy) 150-500 <1	Graphite	10-70	<1
Haynes 230 (Nickel alloy) 150-500 <1 Helium <1	GSM 55: Rubber EPDM + silica	2000-8000	<1
Helium <1 <1 Hydrazine <1	Hastelloy X	70-150	<1
Hydrazine <1 <1 Hydrogen 500-1000 <1	Haynes 230 (Nickel alloy)	150-500	<1
Hydrogen 500-1000 <1 roxyl-terminated polybutadiene 500-1000 70-150 Imide 10-70 <1	Helium	<1	<1
oxyl-terminated polybutadiene 500-1000 70-150 Imide 10-70 <1	Hydrazine	<1	<1
Imide 10-70 <1 Incolloy A286 1-10 <1	Hydrogen	500-1000	<1
Incolloy A286 1-10 <1 Inconel 600 150-500 <1	roxyl-terminated polybutadiene H	500-1000	70-150
Inconel 600 150-500 <1 Inconel 625 70-150 <1	Imide	10-70	<1
Inconel 625 70-150 <1 Inconel 718 500-1000 <1	Incolloy A286	1-10	<1
Inconel 718 500-1000 <1 Iron >19 000 500-1000 Iron powder <1	Inconel 600	150-500	<1
Iron >19 000 500-1000 Iron powder <1	Inconel 625	70-150	<1
Iron powder <1 <1 Iron, ion 10-70 <1	Inconel 718	500-1000	<1
Iron, ion 10-70 <1 Isocyanates <1	Iron	>19 000	500-1000
Isocyanates <1 <1 Lanthanum <1	Iron powder	<1	<1
Lanthanum <1 <1 Lead 10-70 10-70 Lime <1	Iron, ion	10-70	<1
Lead 10-70 10-70 Lime <1	Isocyanates	<1	<1
Lime <1 <1 Liquid hydrogen LH2 150-500 <1	Lanthanum	<1	<1
Liquid hydrogen LH2 150-500 <1 Liquid oxygen LOx 1000-2000 <1	Lead	10-70	10-70
Liquid oxygen LOx 1000-2000 <1 Lithium Cobalt Oxide <1	Lime	<1	<1
Lithium Cobalt Oxide <1 10-70 Lithium Salts <1	Liquid hydrogen LH2	150-500	<1
Lithium Salts <1 1-10 Magnesium 150-500 1-10 Magnesium alloy 70-150 <1	Liquid oxygen LOx	1000-2000	<1
Magnesium 150-500 1-10 Magnesium alloy 70-150 <1	Lithium Cobalt Oxide	<1	10-70
Magnesium alloy 70-150 <1 Manganese 150-500 10-70 Manganese Dioxide <1	Lithium Salts	<1	1-10
Manganese 150-500 10-70 Manganese Dioxide <1	Magnesium	150-500	1-10
Manganese Dioxide <1 <1 Mastic Silicone 10-70 <1	Magnesium alloy	70-150	<1
Mastic Silicone 10-70 <1 Melamine 70-150 <1	Manganese	150-500	10-70
Melamine 70-150 <1 Melamine resin foam 70-150 <1	Manganese Dioxide	<1	<1
Melamine resin foam 70-150 <1 Mercury <1	Mastic Silicone	10-70	<1
Mercury <1 <1 MMH Methylhydrazine <1	Melamine	70-150	<1
MMH Methylhydrazine <1 <1 Molybdenum 150-500 1-10 NEXTEL 10-70 <1	Melamine resin foam	70-150	<1
Molybdenum 150-500 1-10 NEXTEL 10-70 <1	Mercury	<1	<1
NEXTEL 10-70 <1 Nickel 1000-2000 70-150 Nickel alloy 242 150-500 <1	MMH Methylhydrazine	<1	<1
Nickel 1000-2000 70-150 Nickel alloy 242 150-500 <1	Molybdenum	150-500	1-10
Nickel alloy 242 150-500 <1 Nickel, ion 1-10 <1	NEXTEL	10-70	<1
Nickel, ion 1-10 <1 Niobium 10-70 <1	Nickel		70-150
Niobium 10-70 <1 Nitrogen 70-150 1-10 Nitrogen tetroxide N2O4 <1	Nickel alloy 242	150-500	<1
Nitrogen 70-150 1-10 Nitrogen tetroxide N2O4 <1	Nickel, ion	1-10	<1
Nitrogen tetroxide N2O4 <1 <1	Niobium	10-70	<1
	Nitrogen	70-150	1-10
Norcoat 150-500 10-70	Nitrogen tetroxide N2O4	<1	<1
	Norcoat	150-500	10-70

Gold	<1	<1
Graphite	10-70	<1
GSM 55: Rubber EPDM + silica	2000-8000	<1
Hastelloy X	70-150	<1
Haynes 230 (Nickel alloy)	150-500	<1
Helium	<1	<1
Hydrazine	<1	<1
Hydrogen	500-1000	<1
xyl-terminated polybutadiene H	500-1000	70-150
Imide	10-70	<1
Incolloy A286	1-10	<1
Inconel 600	150-500	<1
Inconel 625	70-150	<1
Inconel 718	500-1000	<1
Iron	>19 000	500-1000
Iron powder	<1	<1
Iron, ion	10-70	<1
Isocyanates	<1	<1
Lanthanum	<1	<1
Lead	10-70	10-70
Lime	<1	<1
Liquid hydrogen LH2	150-500	<1
Liquid oxygen LOx	1000-2000	<1
Lithium Cobalt Oxide	<1	10-70
Lithium Salts	<1	1-10
Magnesium	150-500	1-10
Magnesium alloy	70-150	<1
Manganese	150-500	10-70
Manganese Dioxide	<1	<1
Mastic Silicone	10-70	<1
Melamine	70-150	<1
Melamine resin foam	70-150	<1
Mercury	<1	<1
MMH Methylhydrazine	<1	<1
Molybdenum	150-500	1-10
NEXTEL	10-70	<1
Nickel	1000-2000	70-150
Nickel alloy 242	150-500	<1
Nickel, ion	1-10	<1
Niobium	10-70	<1
Nitrogen	70-150	1-10
Nitrogen tetroxide N2O4	<1	<1
Norcoat	150-500	10-70

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Havnes 230 (Nickel alloy)	1 50-150	
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transformer and the	4.50-500	
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Polagramature allery	20-150	10.20
Manganese Disside	10.70	-1
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Month Polarity drastres	4.80-800	1.10
Patienten 1	10 20	70-180
Nickel, Ion	10-20	
	20.150	1-10
		-1
Gold	<1	<1
Graphite	10-70	<1
GSM 55: Rubber EPDM + silica	2000-8000	<1
Hastelloy X	70-150	<1
Haynes 230 (Nickel alloy)	150-500	<1
Helium	<1	<1
	<1	<1
Hydrazine		
Hydrogen	500-1000	<1
xyl-terminated polybutadiene H	500-1000	70-150
Imide	10-70	<1
Incolloy A286	1-10	<1
Inconel 600	150-500	<1
Inconel 625	70-150	<1
Inconel 718		
	500-1000	<1
Iron	>19 000	500-1000
Iron powder	<1	<1
Iron, ion	10-70	<1
Isocyanates	<1	<1
Lanthanum	<1	<1
Lead	10-70	10-70
Lime	<1	<1
Liquid hydrogen LH2	150-500	<1
Liquid oxygen LOx	1000-2000	<1
Lithium Cobalt Oxide	<1	10-70
Lithium Salts	<1	1-10
Magnesium	150-500	1-10
Magnesium alloy	70-150	<1
Manganese	150-500	10-70
-		
Manganese Dioxide	<1	<1
Mastic Silicone	10-70	<1
Melamine	70-150	<1
Melamine resin foam	70-150	<1
Mercury	<1	<1
		<1
	-1	
MMH Methylhydrazine	<1	
MMH Methylhydrazine Molybdenum	150-500	1-10
MMH Methylhydrazine Molybdenum NEXTEL	150-500 10-70	1-10 <1
MMH Methylhydrazine Molybdenum NEXTEL Nickel	150-500 10-70 1000-2000	1-10 <1 70-150
MMH Methylhydrazine Molybdenum NEXTEL	150-500 10-70	1-10 <1
MMH Methylhydrazine Molybdenum NEXTEL Nickel Nickel Nickel alloy 242	150-500 10-70 1000-2000 150-500	1-10 <1 70-150
MMH Methylhydrazine Mölybdenum NEXTEL Nickel Nickel alloy 242 Nickel, Ion	150-500 10-70 1000-2000 150-500 1-10	1-10 <1 70-150 <1 <1
MMH Methylhydrazine Molybdenum NEXTEL Nickel Nickel alloy 242 Nickel, ion Niobium	150-500 10-70 1000-2000 150-500 1-10 10-70	1-10 <1 70-150 <1 <1 <1 <1
MMH Methylhydrazine Molybdenum NEXTEL Nickel Nickel alloy 242 Nickel, ion Niobium Nitrogen	150-500 10-70 1000-2000 150-500 1-10 10-70 70-150	1-10 <1 70-150 <1 <1 <1 <1 1-10
MMH Methylhydrazine Mölybdenum NEXTEL Nickel Nickel alloy 242 Nickel, Ion Niobium	150-500 10-70 1000-2000 150-500 1-10 10-70	1-10 <1 70-150 <1 <1 <1 <1

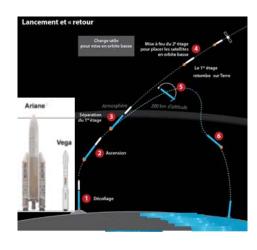
<1
1-10
10-70
70-150
150-500
500-1000
1000-2000
2000-8000
>19 000

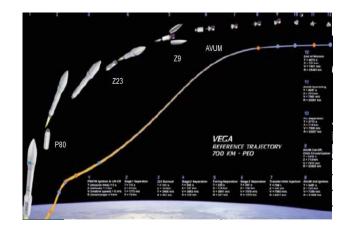
Color code for mass classification of launchers materials (in kg)

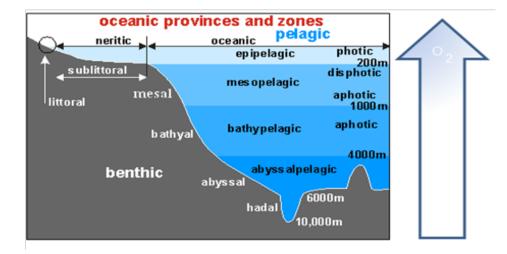
Gold	<1	<1
Graphite	10-70	<1
GSM 55: Rubber EPDM + silica	2000-8000	<1
Hastelloy X	70-150	<1
Haynes 230 (Nickel alloy)	150-500	<1
Helium	<1	<1
Hydrazine	<1	<1
Hydrogen	500-1000	<1
roxyl-terminated polybutadiene H	500-1000	70-150
Imide	10-70	<1
Incolloy A286	1-10	<1
Inconel 600	150-500	<1
Inconel 625	70-150	<1
Inconel 718	500-1000	<1
Iron	>19 000	500-1000
Iron powder	<1	<1
Iron, ion	10-70	<1
Isocyanates	<1	<1
Lanthanum	<1	<1
Lead	10-70	10-70
Lime	<1	<1
Liquid hydrogen LH2	150-500	<1
Liquid oxygen LOx	1000-2000	<1
Lithium Cobalt Oxide	<1	10-70
Lithium Salts	<1	1-10
Magnesium	150-500	1-10
Magnesium alloy	70-150	<1
Manganese	150-500	10-70
Manganese Dioxide	<1	<1
Mastic Silicone	10-70	<1
Melamine	70-150	<1
Melamine resin foam	70-150	<1
Mercury	<1	<1
MMH Methylhydrazine	<1	<1
Molybdenum	150-500	1-10
NEXTEL	10-70	<1
Nickel	1000-2000	70-150
Nickel alloy 242	150-500	<1
Nickel, ion	1-10	<1
Niobium	10-70	<1
Nitrogen	70-150	1-10
Nitrogen tetroxide N2O4	<1	<1
Norcoat	150-500	10-70

Identification and characterization of relevant ecosystems

- Characterization of natural sea ecosystems: typical environmental and biological characteristics of deep sea ecosystem in the zones where launcher residues are known to fall back:
 - The **coastal sea environment** of the ARIANE and VEGA launching ramp in Kourou, French Guyana, that receives most of fuel and lower launching stage residues (especially in the case of VEGA launches, P80) and
 - The **deep sea ecosystem** (abyssal plains) in which are falling most parts of upper launcher stages
- Specific environment conditions : pH, O₂, light, temperature, salinity, organic carbon, microbiota, macrofauna, etc. that will influence the behaviour and degradation of launchers substances in the ocean







Definition of the "neritic" and "oceanic" provinces that are impacted by lower stage and upper stage of ARIANE AND VEGA launchers, respectively

- The degradation products of two families of components were determined :
 - Metals degradation products. They come from the metallic substances or constitutive elements of alloys, They are ions, hydrated ions or oxidized ions
 - Non-metals degradation products (also called organic degradation products). This category gathers mostly resins and polymers, Depending on the aerobic or anaerobic conditions, different chemical substances are released as metabolic products

(Eco)Toxicity of launcher components

- 30 substances out of 178 from the launchers with no quantitative toxicological information available
- 48 substances out of 178 from the launchers with no quantitative ecotoxicological information available
- 26 substances out of 178 identified for which neither toxicological nor ecological quantitative information available
- It must be noted that there is no link between the absence of information on the toxicity and the absence of toxicity or not

Components	Mass in A5-ECA	Mass in VEGA
Bismaleimide Triazine		
Carbon		
Chemosil		
Epoxy resin - curative - 4,4'-DDS diaminodiphenylsulfone		
Glass		
Glass fibre		
Gold		
Helium		
Hydrogen		
Hydroxyl-terminated polybutadiene HTPB		
Lanthanum		
Lithium Cobalt Oxide		
Magnesium alloy		
Mastic Silicone		
Melamine resin foam		
Niobium		
Phenolic resin		
Polyethylene terephthalate PET		
Polyimide PI		
Polyisoprene IR		
Polyphenylene sulfide PPS		
Polypyrrole PPy		
Polyurethane PU		
Silica fibre		
Tetrakis(2-butoxyethyle)orthosilicate		
Viscose		

Substances with no toxicological and ecological information

(Eco)Toxicity of launcher components

- There are 17 substances (out of 178) for which the review has concluded that they are not toxic. This means that those products are not considered to be hazardous for their environment.
- The remaining substances have information about their toxicity or their ecotoxicity.

Components	Mass in A5-ECA	Mass in VEGA
Aramid fibre		
CaCO3		
Carbon		
Carbon Epoxy Fibre		
Cork		
Dow Corning [®] 1200 RTV Prime Coat- Primer		
Ethylene		
Glue CAF 730		
Gold		
Helium		
Hydrogen		
Lanthanum		
Polyethylene terephthalate PET		
Polyisoprene IR		
Polypropylene PP		
Tantalum		
Viscose		

Non toxic substances

Substances with EC50 for aquatic species

Component	A5	VEGA	Aquatics species 🗾
Cadmium	5,5	5,5	0,001
Paint	325	40	0,00
Chlorine	325	0,5	0,014
Copper	1500	325	0,15
Mercury	0,5	0,5	0,35
Sulfur	40	0,5	0,45
Zinc	750	40	0,45
Xylene	325	5,5	3,3
Ethylbenzene	40	5,5	5,1
Toluene	5,5	0,5	7,63
Explosive	40	5,5	7,96
Vinyl acetate	5,5	0,5	14
Dicyclopentadiene	325	0,5	16
Phosphorus	40	5,5	33,2
Phenol	0,5	750	68,8
Potassium hydroxide	5,5	0,5	80
Lead	40	40	126
Lithium Salts	0,5	5,5	158
Graphite	40	0,5	200
Nickel	1500	110	200
Zirconium oxide	40	0,5	200
Alumina	5000	1500	437
Molybdenum	325	5,5	800
Lime	0,5	0,5	1 070
Titanium tetrabutanolate	0,5	0,5	1 925
Antimony trioxide Sb2O3	110	0,5	2 000
EPDM rubber	40	1500	2 000
Petroleum naphtha	5,5	0,5	2 200
Bentonite	110	0,5	19 000
Ceramic	0,5	0,5	20 000
Chromium(III) oxide	0,5	0,5	20 000
CaCO3 (calcium carbonate)	0,5	0,5	56 000

Preliminary risk assessment

- Risk = f [(eco)toxicity, quantity of substance] where f is a function chosen and adapted for each case, often multiplication
- The concentration of substances in the marine environment cannot be assessed here as no models are available to calculate
 - i. the amount of substance effectively released in the water by the launcher and the components, and even less for degradation products,
 - ii. the diffusion rate of substances in the water, which is a non-static open system.
- However, with the hypothesis of all substances released will behave the same (in terms of diffusion) in the ocean, the initial quantity of substance available is the main parameter to compare the exposure.
- The adopted methodology was to multiply the amount of substance and the inverse of the EC50 (1/EC50).
- For the two launchers, the top 5 of the most risk substances is the same: paint, chlorine, cadmium, copper, zinc
- Xylene, alumina, mercury, ethylbenzene, nickel, Sulphur and explosives are also part of the substances that can pose the highest risks to the marine environment

Ranking – from the highest risk (in red) to the lowest (no color) – of the substances for which EC50s of fishes were available in each launcher

Component, for A5PaintChorineChorineCopperCadmiumZincZincTop 5ChlorineXyleneSulfurDicyclopentadieneAluminaDicyclopentadieneAluminaDicyclopentadieneAluminaMercuryEthylbenzeneTop 10SulfurNickelExplosivePhosphorusTop 15LeadMolybdenumVinyl acetateGraphiteZirconium oxidePhenolBentoniteLithium saltsPitoleum naphthaPetroleum naphthaLithium saltsPetroleum naphthaChromium(III) oxideCaramicChromium(III) oxideCaco3 (calcium carbonate)		each launcher	
PaintPaintChlorineCadmiumCopperCadmiumCadmiumCopperCadmiumTop 5ChlorinePhenolXylenePhenolSulfurXyleneDicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10NickelEthylbenzeneExplosiveEthylbenzenePhosphorusEthylbenzenePhosphorusNickelPhosphorusPhosphorusVinyl acetatePhosphorusVinyl acetateVinyl acetateCirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphiteLithium saltsTitanium tertabutanolatePetroleum naphthaTitanium tertabutanolateChromium(III) oxideChromium(III) oxide	Component, for A5		Component, for VEGA
Copper CadmiumCopper ZincZincTop 5ChlorineXylenePhenolSulfurAluminaDicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10SulfurSulfurNickelEthylbenzeneExplosiveEPDM rubberMercuryNickelTolueneTop 15LeadMolybdenumVinyl acetateTolueneLindDicyclopentadieneAuminaPhosphorusNickelDicyclopentadieneTolueneTop 15LeadVinyl acetateCirconium oxideDicyclopentadienePotassium hydroxideMolybdenumPhenolZirconium oxidePhenolLithium saltsEPDM rubberGraphiteLithium saltsPitoleum naphthaLimeLimeTitanium tetrabutanolatePetroleum naphthaTitanium tetrabutanolateBentoniteLimeCeramicChromium(III) oxideChromium(III) oxide	Paint		Paint
CadmiumZincZincTop 5ChlorineXylenePhenolSulfurAluminaDicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10SulfurSulfurNickelEthylbenzeneExplosiveEPDM rubberMercuryNickelTolueneTop 15MolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumPhenolGraphiteZirconium oxidePotassium hydroxidePhenolErPDM rubberPhenolTitanium tetrabutanolateAntimony trioxide Sb2O3Fitanium tetrabutanolateLimeTitanium tetrabutanolateChromium(III) oxideBentoniteLimeCeramicChromium(III) oxideChromium(III) oxide	Chlorine		Cadmium
ZincTop 5ChlorineXylenePhenolSulfurAluminaDicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10SulfurEthylbenzeneExplosiveEthylbenzeneExplosiveEPDM rubberMercuryNickelPhosphorusNickelTolueneTop 15LeadPhosphorusVinyl acetateTolueneLeadVinyl acetateZirconium oxideDicyclopentadienePotassium hydroxideDicyclopentadienePhonolZirconium oxidePhenolLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaTitanium tetrabutanolateChromium(III) oxideChromium(III) oxide	Copper		Copper
XylenePhenolSulfurAluminaDicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10SulfurEthylbenzeneExplosiveEthylbenzeneExplosiveEPDM rubberMercuryNickelPhosphorusNickelTolueneTop 15LeadPhosphorusVinyl acetateTolueneLeadVinyl acetateZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxidePhenolLimeLithium saltsTitanium tetrabutanolateLimeTitanium tetrabutanolateChromium(III) oxideChromium(III) oxide	Cadmium		Zinc
SulfurAluminaDicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10NickelEthylbenzeneExplosiveEPDM rubberMercuryExplosiveMercuryExplosivePhosphorusNickelTolueneTop 15LeadPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimeTitanium tetrabutanolateChromium(III) oxideChromium(III) oxide	Zinc	Top 5	Chlorine
DicyclopentadieneXyleneAluminaMercuryEthylbenzeneTop 10NickelEthylbenzeneExplosiveEPDM rubberMercuryExplosiveMercuryNickelTolueneTop 15LeadYinyl acetateUinyl acetateVinyl acetateLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimeTitanium tetrabutanolateChromium(III) oxideEntoniteChromium(III) oxideChromium(III) oxide	Xylene		Phenol
AluminaMercuryEthylbenzeneTop 10SulfurNickelEthylbenzeneExplosiveEPDM rubberMercuryExplosivePhosphorusNickelTolueneTop 15LeadMolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteDicyclopentadieneZirconium oxideDicyclopentadienePotassium hydroxideGraphiteEPDM rubberGraphiteEPDM rubberGraphiteZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Eronium oxideEthylbenzeneZirconium oxideEhtylbenzeneZirconium oxideEntoniteLimeLithium saltsPetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Sulfur		Alumina
EthylbenzeneTop 10SulfurNickelEthylbenzeneExplosiveEPDM rubberMercuryExplosivePhosphorusNickelTolueneTop 15MolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePhenolGraphiteEPDM rubberGraphiteDinyl acetateDicyclopentadienePotassium hydroxidePotassium hydroxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaBentoniteLimeEntoniteCeramicCeramicChromium(III) oxideChromium(III) oxide			Xylene
NickelEthylbenzeneExplosiveEPDM rubberMercuryExplosivePhosphorusNickelTolueneTop 15LeadPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphiteLithium saltsZirconium oxideDetroleum naphthaLimeTitanium tetrabutanolateBentoniteLimeTitanium tetrabutanolateCeramicCeramicChromium(III) oxideChromium(III) oxide	Alumina		Mercury
ExplosiveEPDM rubberMercuryEPDM rubberPhosphorusNickelTolueneTop 15MolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphiteLithium saltsZirconium oxidePhenolLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Ethylbenzene	Top 10	Sulfur
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PhosphorusNickelTolueneTop 15LeadMolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphiteLithium saltsZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaPetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Explosive		EPDM rubber
TolueneTop 15LeadMolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideLithium saltsLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaPetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Mercury		Explosive
MolybdenumPhosphorusVinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphiteZirconium oxideLimeEPDM rubberZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Phosphorus		Nickel
Vinyl acetateTolueneLeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Toluene	Top 15	Lead
LeadVinyl acetateGraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Molybdenum		Phosphorus
GraphiteLithium saltsZirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Vinyl acetate		Toluene
Zirconium oxideDicyclopentadienePotassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaCeramicCeramicChromium(III) oxideChromium(III) oxide	Lead		Vinyl acetate
Potassium hydroxideMolybdenumAntimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Graphite		Lithium salts
Antimony trioxide Sb2O3Potassium hydroxideEPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Zirconium oxide		Dicyclopentadiene
EPDM rubberGraphitePhenolZirconium oxideBentoniteLimeLithium saltsTitanium tetrabutanolatePetroleum naphthaAntimony trioxide Sb2O3LimePetroleum naphthaTitanium tetrabutanolateBentoniteCeramicCeramicChromium(III) oxideChromium(III) oxide	Potassium hydroxide		Molybdenum
Phenol Zirconium oxide Bentonite Lime Lithium salts Titanium tetrabutanolate Petroleum naphtha Antimony trioxide Sb2O3 Lime Petroleum naphtha Titanium tetrabutanolate Bentonite Ceramic Ceramic Chromium(III) oxide Chromium(III) oxide	Antimony trioxide Sb2O3		Potassium hydroxide
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Lithium salts Titanium tetrabutanolate Petroleum naphtha Antimony trioxide Sb2O3 Lime Petroleum naphtha Titanium tetrabutanolate Bentonite Ceramic Ceramic Chromium(III) oxide Chromium(III) oxide	Phenol		Zirconium oxide
Petroleum naphtha Antimony trioxide Sb2O3 Lime Petroleum naphtha Titanium tetrabutanolate Bentonite Ceramic Ceramic Chromium(III) oxide Chromium(III) oxide	Bentonite		Lime
Lime Petroleum naphtha Titanium tetrabutanolate Bentonite Ceramic Ceramic Chromium(III) oxide Chromium(III) oxide	Lithium salts		Titanium tetrabutanolate
Titanium tetrabutanolate Bentonite Ceramic Ceramic Chromium(III) oxide Chromium(III) oxide	Petroleum naphtha		Antimony trioxide Sb2O3
Ceramic Ceramic Chromium(III) oxide Chromium(III) oxide	Lime		Petroleum naphtha
Chromium(III) oxide Chromium(III) oxide	Titanium tetrabutanolate		Bentonite
	Ceramic		Ceramic
Caco3 (calcium carbonate) Caco3 (calcium carbonate)	Chromium(III) oxide		Chromium(III) oxide
	Caco3 (calcium carbonate)		Caco3 (calcium carbonate)

Estimation of behaviour and toxicity of components of launchers in marine conditions

- Literature review for fate and behaviour of Ariane and Vega components and materials
- Metallic corrosion in seawater and toxicity were followed in a range of conditions for a set of representative alloys used in aerospace vessels
- Similar experiments were performed for a set of representative organic components of Vega and & Ariane 5 launchers
- Follow-ups were performed in representative ecosystems (French Guiana)

Selected materials

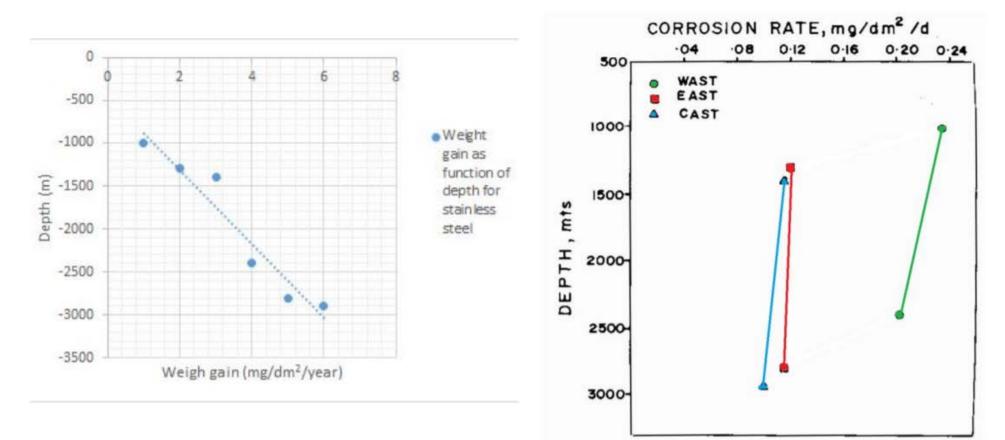
metals	non-metals
Stainless steel	Epoxy resin
Aluminium 2024	Phenolic resin
Titanium 6AI 4V	Polyurethane

Metallic compounds

Literature review On-site studies in French Guyana Model experiments in laboratory conditions

Metallic corrosion as a function of depth

Very limited relevant bibliography is available on the "Biodegradation" or "biofilm allowing corrosion" for alloys used in launcher composition and aerospace manufacture



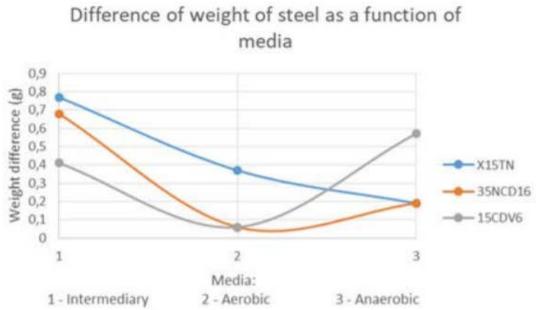
weight gain and corrosion rates as a function of depth for various metalic alloys (adapted from Sawant and Wagh, 1990)



Metallic corrosion as a function of composition and marine oxygen level

• Corrosion in seawater estimated from weight in aerobic, anaerobic and mixed conditions (our work, unpublished results)

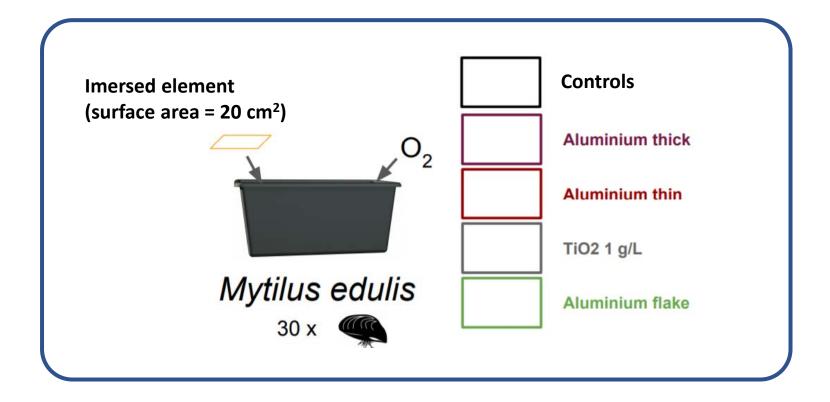
Steel	2 2	Weight before	Weight after	difference	Diffe
	Tank 1	120,36	119,59	0,77	0,9
X15TN	Tank 2	120,05	119,68	0,37	a 0,8 a 0,7
	Tank 3	120,08	119,89	0,19	0,6
	Tank 1	122,88	122,2	0,68	0,7 0,6 0,5 0,4
35NCD16	Tank 2	123,66	123,6	0,06	tų 0,3
	Tank 3	122,89	122,7	0,19	0,3 0,2 0,1
	Tank 1	122,7	122,29	0,41	0
15CDV6	Tank 2	122,44	122,38	0,06	1
	Tank 3	122,56	121,99	0,57	1 - Intern





Ecotoxicity evaluation

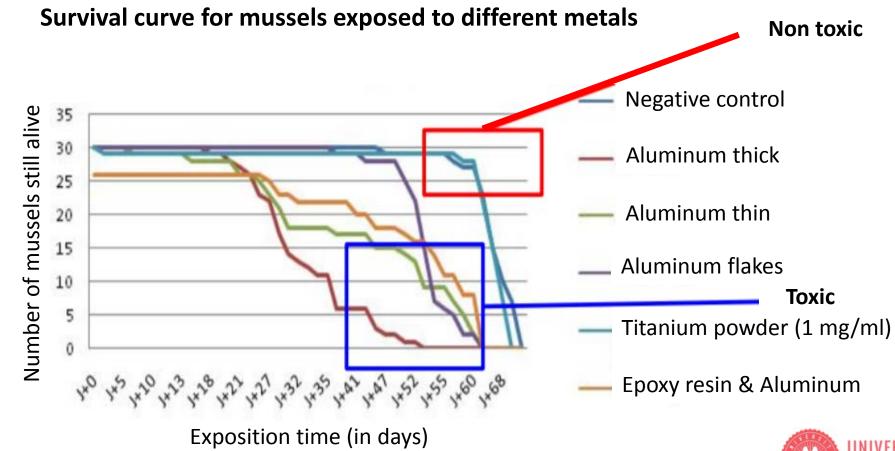
Macrofauna in vitro





Ecotoxicity evaluation

Macrofauna in vitro





IN SITU IMPACT STUDIES in French Guyana

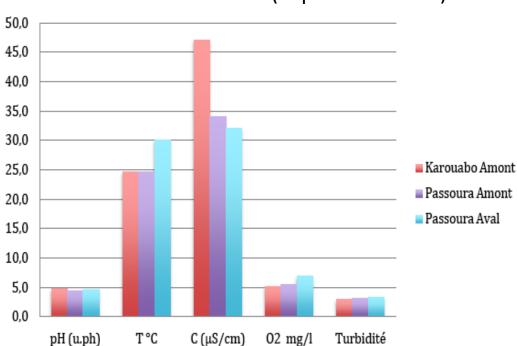
- Water Quality

- Turbidity, Ph & Conductivity values are low
- Clear waters
- Physico-chemical characteristics of the environment change according to the season

Fish populations

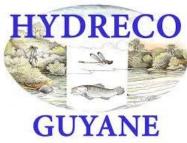
- Sites in good environmental health
- Strong imbalance in local fish population distribution (Vigouroux & Guillemet, 2006)

Therefore, the successive launches of Ariane can induce the release of various products into the environment (including aluminum), with potentially a non-negligible impact on fish



In situ measurements (September 2014)



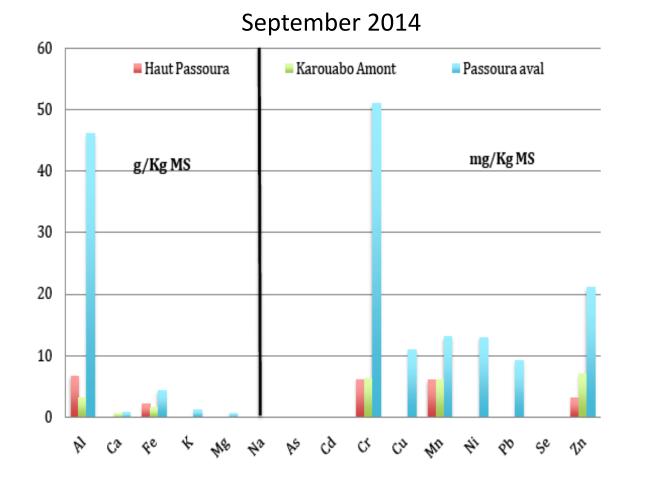


NTU

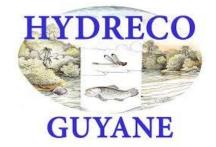
IN SITU IMPACT STUDIES in French Guyana

Sediment status

In some locations, aluminum concentrations are high



Anthropogenic contaminations ?



Organic compounds

Literature mining

Behavior in seawater

Ecotoxicological assessment in laboratory conditions

no toxicological data

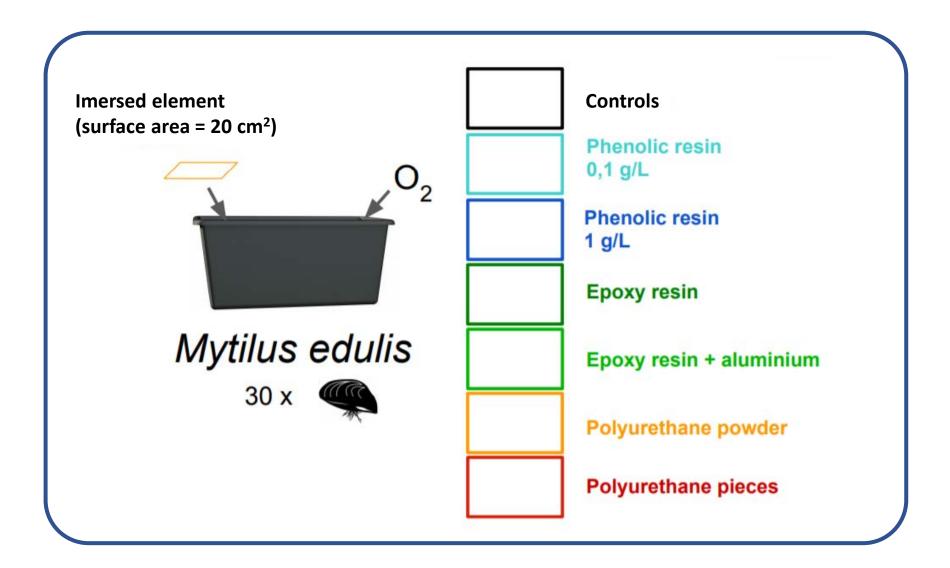
	Component
	Aluminium
	Bismaldeide triazine
	Larbon
	Chemosil
	Chromium
	Epoxy resin - curative - 4,4-DDS
	diaminodiphenylsulfone
	Glass
_	Glass fibre
	Gold
	Hellum
	Hydrogen
	Hydroxyl-terminated polybutadiene HTPB
	Lanthanum
	Lithium Cobalt Oxide
	Magnesium
	Magnesium alloy
	Mastic Silicone
	Melamine resin foarn
	Niobium
	Phenolic resin
	Polyethylene terephthalate PET
·	Polyimide Pl
	Polyisoprene IR
13	Polyphenytene sultide PPS
	Polypyrrole PPy
	Polyurethane PU
	Polyvinyl chloride PVC
	Silica fibre
	Tetrakis(2-butoxyethyle)orthosilicate
	Zinc
	Zirconium oxide

no ecological data

Components	
Antimony	Nylon
BeO (beryllium oxide)	Paper
Bismaldeide triazine	Phenol formaldehyde resin
	phenolic resin
Chemosil	Polycarbonate PC
Cobalt	Polyethylene terephthalate PET
Epoxy resin - curative - 4,4'-DDS diaminodiphenylsulfone	Polyimide Pl
Epoxy resin (MY720)	Polyisoprene IR
Glass	Polyphenylene sulfide PPS
Glassfibre	Polypyrrole PPy
Glue Wacker T77	Polytetrafluoroethylene PTFE (Tetion)
Gold	Polyurethane PU
Helium	Silica
Hydrogen	Silica fibre
Hydroxyl-terminatedpolybutadiene HTPB	Silicon
Lanthanum	Silicon rubber
Lithium Cobalt Oxide	Silver
Magnesium alloy	Tetrakis(2-butoxyethyle) orthosilicate
Manganese Dioxide	Titanium
Mastic Silicone	Titanium dioxide
Melamine	Tungsten
NEXTEL	Vanadium
Melamine resin foam	Viscose
Niobium	Zirconium
Nitrogen tetroxide N2O4	

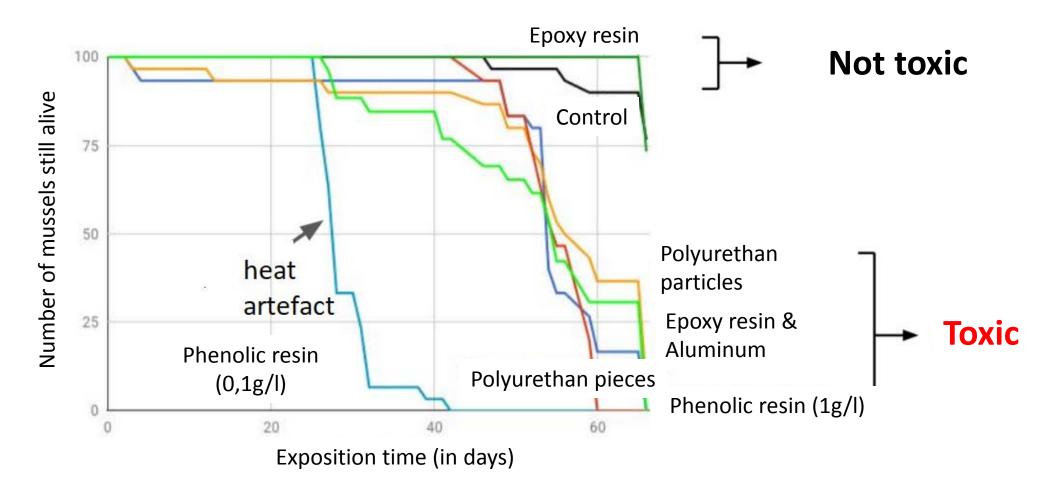
Ecotoxicity evaluation

Macrofauna in vitro



Ecotoxicity evaluation

Macrofauna in vitro



Survival curves for mussels exposed to components

conclusions

- Behaviour and toxicity varies depending on substrate but also on environmental conditions (e.g. depth, oxygen availability)
- Time has also to be taken into consideration, no rapid conclusion can be driven from available literature and experimental approach during the project
- Longer impact has to be investigated



Thank you for your attention!

Any questions?







Functional Ecology to Reduce Launchers Impact on Deep Sea (ESA AO 1-8623/16/NL/KML)