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From sub cellular to community level: Toxicity of glutaraldehyde to several aquatic organisms

Susana P.P. Pereira *[,1], Rhaul Oliveira *[,1], Sónia Coelho, Carolina Musso, Amadeu M.V.M. Soares, Inês Domingues, António J.A. Nogueira

Department of Biology & CESAM, University of Aveiro, 3810-193 Aveiro, Portugal

HIGHLIGHTS

- Toxicity of glutaraldehyde to aquatic organisms of different trophic levels was assessed.
- GA was only toxic at mg/l range with more severe effects on microcrustaceans.
- Inhibition of biomarkers was observed in *Danio rerio* adults and embryos.
- GA causes hatching delay and malformations that could imply chronic effect for fish.

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ABSTRACT

The biocide glutaraldehyde (GA) is widely used as a disinfectant and sterilizing agent against bacteria and virus in hospital and veterinary facilities. GA or its metabolites may reach aquatic ecosystems due to incomplete or inadequate treatment of wastewaters. Data about GA effects at lethal and a sub lethal level to non-target organisms is needed so that a risk assessment to aquatic ecosystems can be done. Thus, in this work a battery of toxicity tests with primary producers, primary consumers and secondary consumers were performed and a species sensitive distribution (SSD) for GA was built. Moreover, effects on biomarkers (catalase, lactate dehydrogenase, glutathione-S-transferase, and cholinesterase) were measured in *Danio rerio* embryos and adults. Primary consumers (*Thamnocephalus platyurus* 24 h — EC50 = 3.6 mg/l; *Daphnia magna* 48 h — EC50 = 6.6 mg/l) and *D. rerio* adults (96 h — LC50 = 5.5 mg/l) were slightly more sensitive to GA than *D. rerio* embryos (96 h — LC50 = 22.2 mg/l) and primary producers (*Lemna minor* 168 h — EC50 = 73.8 mg/l; *Pseudokirchneriella subcapitata* 72 h — EC50 = 12.3 mg/l; *Chlamydomonas reinhardtii* 72 h — EC50 = 14.6 mg/l; *Chlorella vulgaris* 72 h — EC50 = 31.3 mg/l). However, no significant differences between the trophic levels were found and general HC5 and HC50 values of 0.6 and 11.4 mg/l were respectively estimated. Despite the low GA toxicity to *D. rerio* embryos, hatching delay and malformations were found (96 h — EC50 = 11.9 mg/l). For biomarkers, an inhibition of lactate dehydrogenase activity was observed in embryos whereas an inhibition in catalase, lactate dehydrogenase and glutathione-S-transferase activities was observed in adults. Thus, GA is moderately toxic (doses > 1 mg/l) to aquatic organisms, independently of the trophic level. However, considering the varied range of effects depending on the life stage and organism tested and relatively low HC5 value of 0.6 mg/l, mesocosm and chronic toxicity tests seem to be the next step in direction of more realistic scenarios of GA risk assessment in aquatic ecosystems.

1. Introduction

The biocide glutaraldehyde (GA) is widely used as disinfectant and sterilizing agent against bacteria and virus. Its biocidal properties are caused by the cross-linking of amine groups in the cell membranes of microorganisms (Boillot and Perrodin, 2007), such as Gram-negative bacteria, fungi, and virus (Simões et al., 2011). GA is mainly used for disinfection in hospital and livestock production facilities (e.g. aquaculture); other applications include hardener in X-ray film processing, biocide in the paper pulp and petroleum industries, embalming agent (e.g. microscopy), preservative for canned food and cosmetics.

Particularly in hospitals, high amounts of GA are daily used for sterilization with concentrations between 0.50 and 3.72 mg/l being already

* Corresponding authors. Tel.: +351 234 370 350; fax: +351 234 372 587.
E-mail addresses: susanapinper@gmail.com (S.P.P. Pereira), rhaul.oliveira@gmail.com (R. Oliveira), sonia.d.coelho@gmail.com (S. Coelho), cmusso86@gmail.com (C. Musso), asoares@ua.pt (A.M.V.M. Soares), inesd@ua.pt (I. Domingues), antonio.nogueira@ua.pt (A.J.A. Nogueira).
[1] The two authors contributed equally to the study.

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Table 1
Glutaraldehyde effects on different aquatic organisms.

Species	Value (mg/l)[a]	Endpoint	Effect	Exposure	Time (days)	Reference
Primary producers						
Pseudokirchneriella subcapitata	3.9	ILm[b]	Biomass	—	4	Vilkas (1974) as cited in OECD SIDS (1998)
	0.81	EC_{50}	Biomass	—	5	WIL (1997) as cited in Leung (2001a)
	0.5	NOEC	Growth			
	0.31	IC_{50}	Growth	Static	4	USEPA (2000)
	0.042	NOEC				
	0.75	IC_{50}	Growth	Static	5	
	0.5	NOEC				
	3.95	EC_{50}	D.O.P.[c]	Static	2	Chen et al. (2005)
	13.2	EC_{50}	Growth			
	1	IC_{50}	Growth	Static	4	Sano et al. (2005)
	0.7	NOEC				
	1.4	LOEC				
	1.8	IC_{50}				
	1.3	NOEC				
	2.1	LOEC				
Scenedesmus subspicatus	0.97	EC_{50}	Biomass	—	4	RCC (1990)
	0.31	NOEC				
	1	EC_{50}	Growth	—	4	NICNAS (1994) as cited in Boillot and Perrodin (2007)
Skeletonema costatum	0.17	EC_{50}	Growth	—	3	SINTEF (1991) as cited in Leung (2001a)
	0.92	EC_{50}	Growth	—	3	SPL (1997) as cited in Leung (2001a)
	0.61	EC_{50}	Biomass			
	0.33	NOEC	Growth			
Primary consumers						
Acartia tonsa	0.11	LC_{50}	—	Static	2	SPL (1997) as cited in Leung (2001a)
	0.029	NOEC				
Artemia sp.	27	LC_{50}	Survival	Static	3	Sano et al. (2004)
Americamysis bahia	7.1	LC_{50}	—	Flow Through	4	SLI (1993a) as cited in Leung (2001a)
	0.78	NOEC				
	7.1	LC_{50}	—	Flow Through	4	USEPA (2000)
	5.5	(early juvenile)				
	20.6	LC_{50} (adults)		Static		
Balanus improvisus	7.5	LC_{50}	—	Static	10	SINTEF (1991) as cited in Leung (2001a)
Carcinus maenas	1100	LC_{50}	m	Static	2	UCC (1975) as cited in OECD SIDS (1998)
	465	LC_{50}			4	
Ceriodaphnia dubia	9	LC_{50}	Survival (neonates)	Static	1	Sano et al. (2003)
	10	LC_{50}	Survival (adults)		1	
	4.7	LC_{50}				
	2.4	NOEC	Survival	Semi-static	8	Sano et al. (2005)
	4.9	LOEC				
	4.7	LC_{50}				
	2.4	NOEC	Reproduction			
	4.9	LOEC				
	4.9	NOEC	Growth			
Chaetogammarus marinus	582	LC_{50}	Survival	Semi-static	1	Adema and Bakker (1984) as cited in OECD SIDS (1998)
	304				2	
	208				3	
	191				4	
	56	NOEC			4	
Crassostrea virginica	0.55	LC_{50}	—	Static	2	UCC (1975) as cited in Leung (2001a)
	0.78	LC_{50}	—	Flow Through	4	SLI (1993b) as cited in Leung (2001a)
	0.16	NOEC				
	0.75	EC_{50}	Intoxication	Flow Through	4	USEPA (2000)
	<0.089	NOEC				
Daphnia magna	>25	LC_{50}	Survival	Static	1	UCC (1977a) as cited in OECD SIDS (1998)
	16.3	LC_{50}			2	
	8	NOEC				
	0.35	LC_{50}	Survival	Static	2	Vilkas (1978a) as cited in OECD SIDS (1998)
	5	LC_{50}	Survival	Static	2	UCC (1981) as cited in Leung (2001a)
	2.1	NOEC	Reproduction	Semi-static	21	CCR (1990) as cited in Leung (2001a)
	16.3	LC_{50}	Survival	—	2	NICNAS (1994) as cited in Boillot and Perrodin (2007)
	4.3	LOEC	Reproduction		21	
	0.75	EC_{50}	Intoxication	Static	2	USEPA (2000)
	3.5	EC_{50}				
	6.7	EC_{50}				
	14.6	EC_{50}				
	8.5	NOEC	—	Semi-static	22	USEPA (2000)
	4.25	LOEC				
	14	LC_{50}	Survival (neonates)	Static	1	Sano et al. (2003)
	56	LC_{50}	Survival (adults)			
	21	LC_{50}	Survival (neonates)	Static	1	Sano et al. (2004)
	20.0	EC_{50}	Immobilization	Static	1	Boillot and Perrodin (2007)
Dreissena polymorpha	21	LC_{50}	Survival	Static	2	Sano et al. (2004)
Hyalella azteca	289	LC_{50}	Survival	Static	1	Sano et al. (2003)