Monitoring the Aquatic Environment
Using Sensor Technologies
The Royal Society of Chemistry
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London, UK

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Sensing Systems For Rapid Characterisation of Water Contamination

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Presentation Overview

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- **Environmental quality**
- **Sensing water quality**
- **Toxicity assays**
- **Novel device for assessing toxicity: Shrimpometer**

Environmental quality

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- **Chemical** analysis using water quality sensors and analytical techniques
- **Eco-assessment** using biological tools such as bio-indicators, bioassays, biomarkers and biosensors.
- **Toxicity assays** using single and multi species such as microorganisms, invertebrates, fish and algae.

Sensing water quality

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- Main uses of water quality sensors are in:
  - ✓ discharge monitors

  - ✓ portable instruments

  - ✓ fixed-site monitors

Sensing water quality

- They exploit:
  - ✓ Electrochemical
  - ✓ Optical
  - ✓ Biochemical techniques
  - ✓ Standardized laboratory methods
- Commercially available instruments are usually big and complex with several sensors to measure a range of contaminants including ammonia, phosphate and nitrate (Bogue, 2008).
- There are also more specialised sensors such as sensors for monitoring boreholes and detecting jet fuel run-off from airports and pipeline leak detection systems.

Sensing water quality

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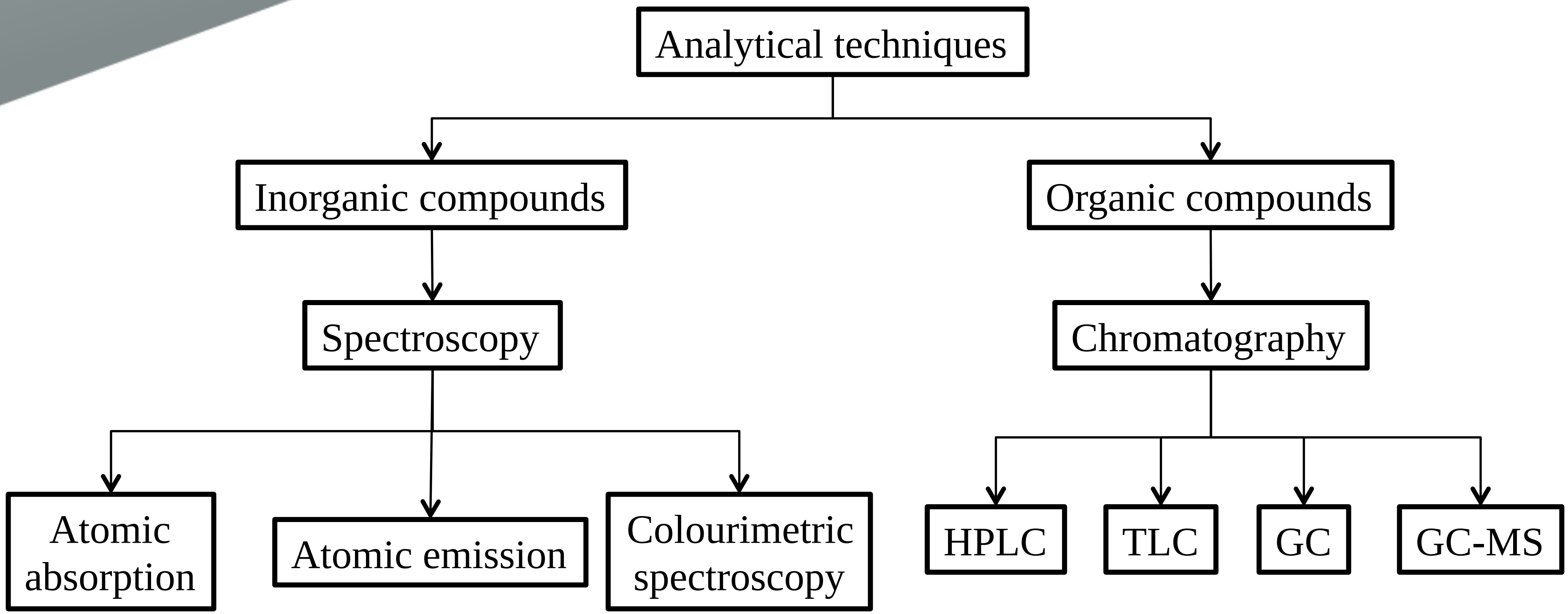
Water Quality sensing techniques (Bogue, 2008).

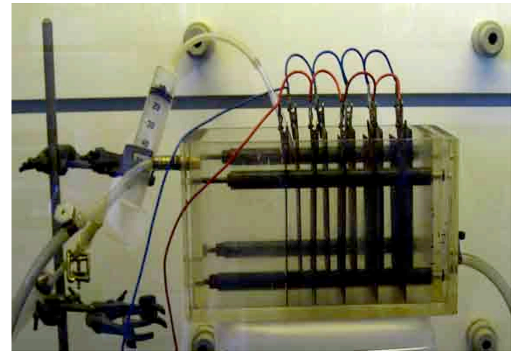
Compound	Techniques
Ammonia, phosphates	ISE, colour chemistry plus photometry, auto titration
Nitrates	ISE, UV absorption, colour chemistry plus photometry
Metals	Voltammetry, colour chemistry plus photometry
Oils/fuels/solvents	UV fluorescence, UV photometry, electromagnetic absorption, optical scatter and reflection, capacitive, vapour purging plus VOC gas sensor
BOD	Bacterial biosensor, biomass oxygen consumption
COD	Thermal/chemical oxidation plus IR-based CO_2 detection, ozone oxidation/consumption, UV/visible spectrometry (inferential method)
TOC	Oxidation plus IR-based CO_2 detection, UV/visible spectrometry (inferential)
Toxicity	Bacterial oxygen consumption, algal fluorescence, microbial respiration inhibition
DO	Clark electrode, fluorescence quenching
SS/turbidity	IR and visible light scatter, optical absorption
Conductivity	Current flow between two electrodes
Total ion concentration/TDS	Conductivity sensor
pH	Glass electrode
Algae/chlorophyll	UV fluorescence

Notes: ISE – ion-selective electrode; TOC – total organic carbon; TDS – total dissolved solids

Characterisation of contaminants



My research…



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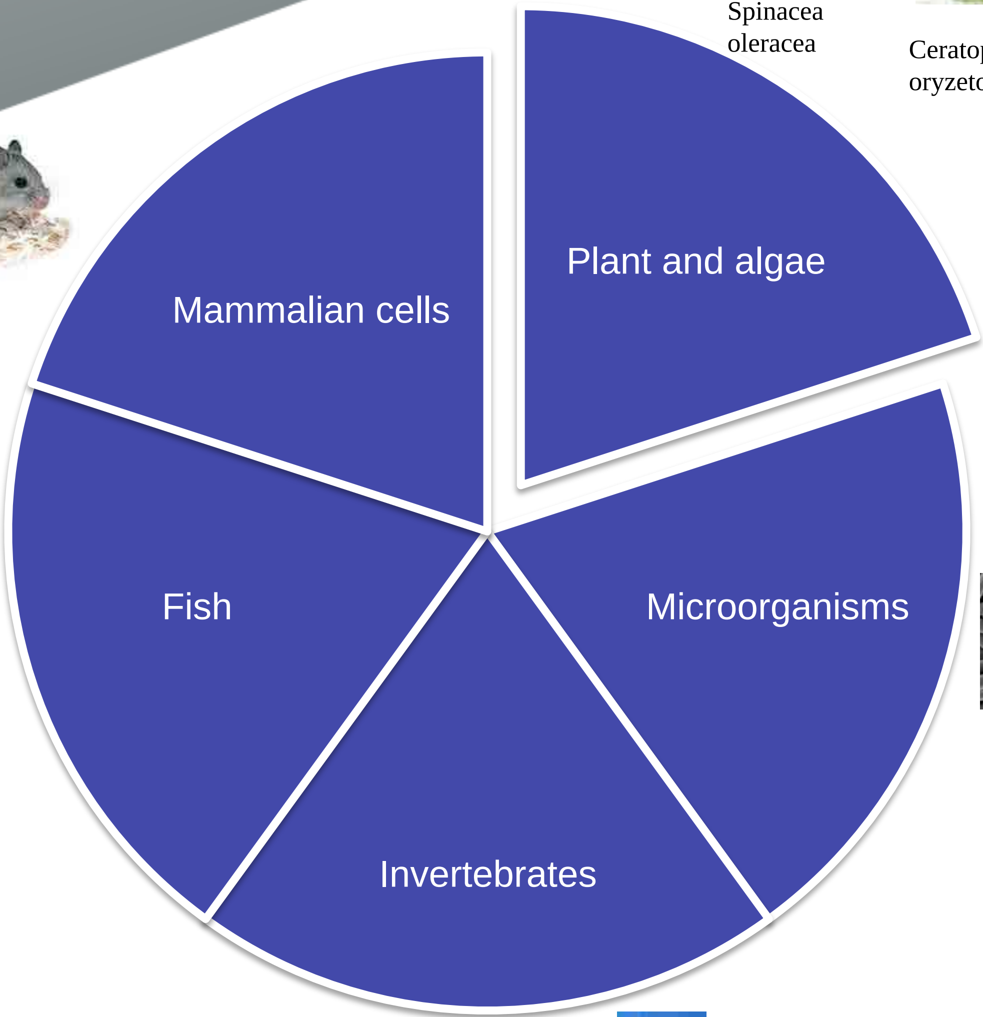
To treat highly contaminated wastewater effectively using electrochemical peroxidation (ECP) and produce water with the minimum of toxicity levels assessed by a set of assays in order to enter the conventional wastewater treatment system.

ECP: A wastewater remediation treatment which is based on the production of hydroxyl radicals by the reaction of hydrogen peroxide with Fe^{2+} → degradation of the organic pollutants

Result: Large chain molecules broke down to smaller → more mobile and more toxic.

Toxicity assays

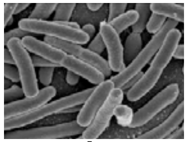



Spinacea oleracea


Ceratophyllum oryzetorum


Ranunculus trichophyllus


Chinese hamster

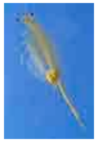

E.coli


P.aeruginosa


S.aureus


Zebrafish


D.magna


Artemia salina

Development of a novel device

AIM:

To built a **simple**, **low-cost** and **sensitive** tool to detect toxic compounds in aqueous solutions regardless the number of tested organisms

HYPOTHESIS:

The effect of toxic compounds on *Artemia* nauplii can be assessed by the decrease of their mobility even at low concentrations

KEY IDEA:

The detection of subtle changes in the mobility of *Artemia salina* nauplii in toxic environment using advanced software.

Artemia species

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***Artemia* species** or brine shrimps (i.e *A. salina*, *A. franciscana*, *A. parthenogenetica*) belong to the phylum Arthropoda and to class Crustacea and are widely used for toxicity studies.

Survival conditions :

Salinity levels	fresh water – 300ppt
Temperature	15-55°C
pH	>7.5

Artemia species endpoints

1. Determination of LD_{50} → ARC-test
2. Hatchability of the cysts
3. Different age specimens
4. Disruption of enzyme properties
5. Loco motor behaviour of the nauplii

Previous Research

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US005789242A

United States Patent [19]

Portmann et al.

[11] **Patent Number: 5,789,242**

[45] **Date of Patent: Aug. 4, 1998**

[54] **METHOD AND DEVICE FOR DETERMINING TOXICITY AS WELL AS THE USE THEREOF**

3345196	7/1985	Germany .	
3922358	1/1991	Germany	G01N 33/18
WO 901286	11/1990	WIPO .	
WO9012886	11/1990	WIPO	C12Q 1/00

Behavior Research Methods, Instruments, & Computers
2001, 33 (3), 398-414

EthoVision: A versatile video tracking system for automation of behavioral experiments

LUCAS P. J. J. NOLDUS, ANDREW J. SPINK, and RUUD A. J. TEGELENBOSCH
Noldus Information Technology, Wageningen, The Netherlands

Weaknesses of previous research

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❖ ***Implementation of patent by Portmann et al (1998)***

- ✓ Type of sample containers
- ✓ Type of illumination (orientation, type of light source, etc)
- ✓ No further research based on this patent
- ✓ Low accuracy (12-36 images/sample with 256x256 pixels)

❖ ***Commercially available software e.g. Ethovision***

- ✓ Unsuitable for tracking large number of organisms.
- ✓ No published work has estimated IC_{50} values using this software.

Implementation of a device…

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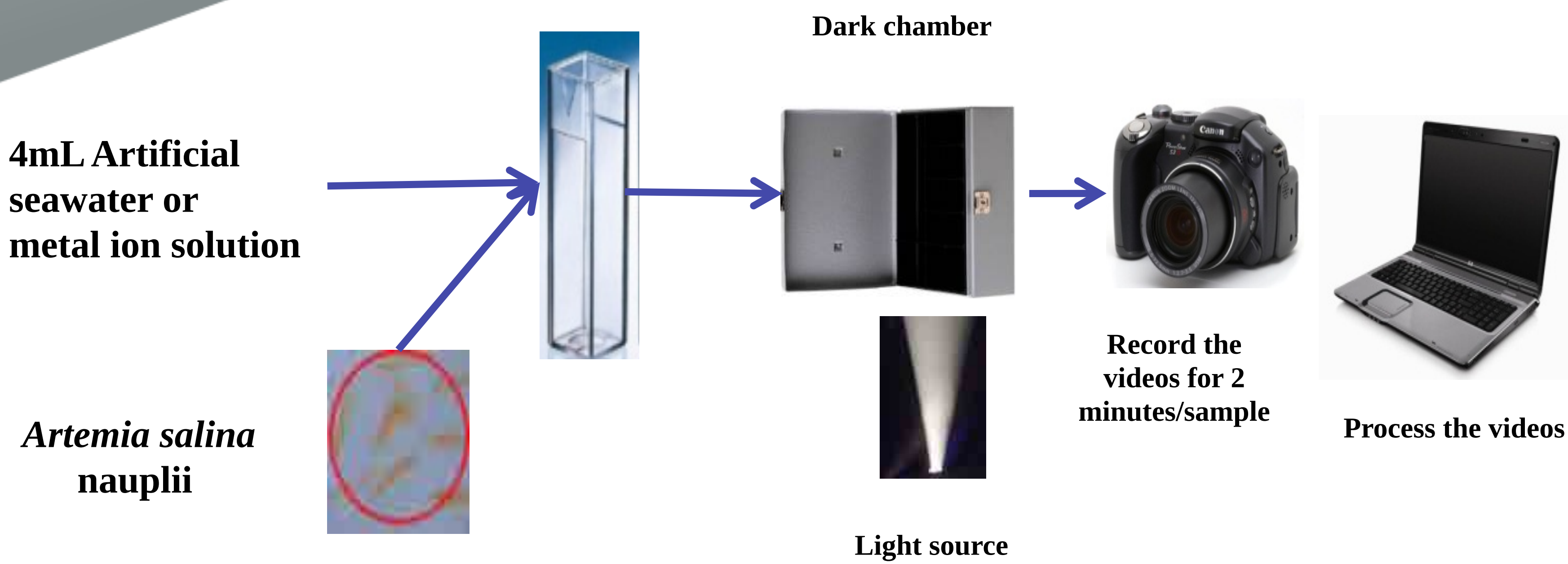
- Capable of tracking large number of organisms simultaneously
- Supports high resolution video (30fps with 640x480 pixels)
- Estimates IC_{50} values for isolated contaminants
- Designed to reduce the effect of light reflections
- Sensitive to a wide range of contaminants
- Low-cost and easy to use

Experimental Part: the process



- An image-processing algorithm for tracking the organisms, running on a laptop computer

What is measured with this algorithm…

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The mobility of the shrimps is derived as a percentage ratio of the average speed of shrimps between the sample and the control

$$mobility(\%) = \frac{\bar{u}_{sample}}{\bar{u}_{control}} 100$$

- If the environment is toxic then the movement of the nauplii deteriorates.
- The speed was assessed and divided to the speed of the control with same number of shrimps under optimum conditions of temperature and salinity.

Demo in ASW

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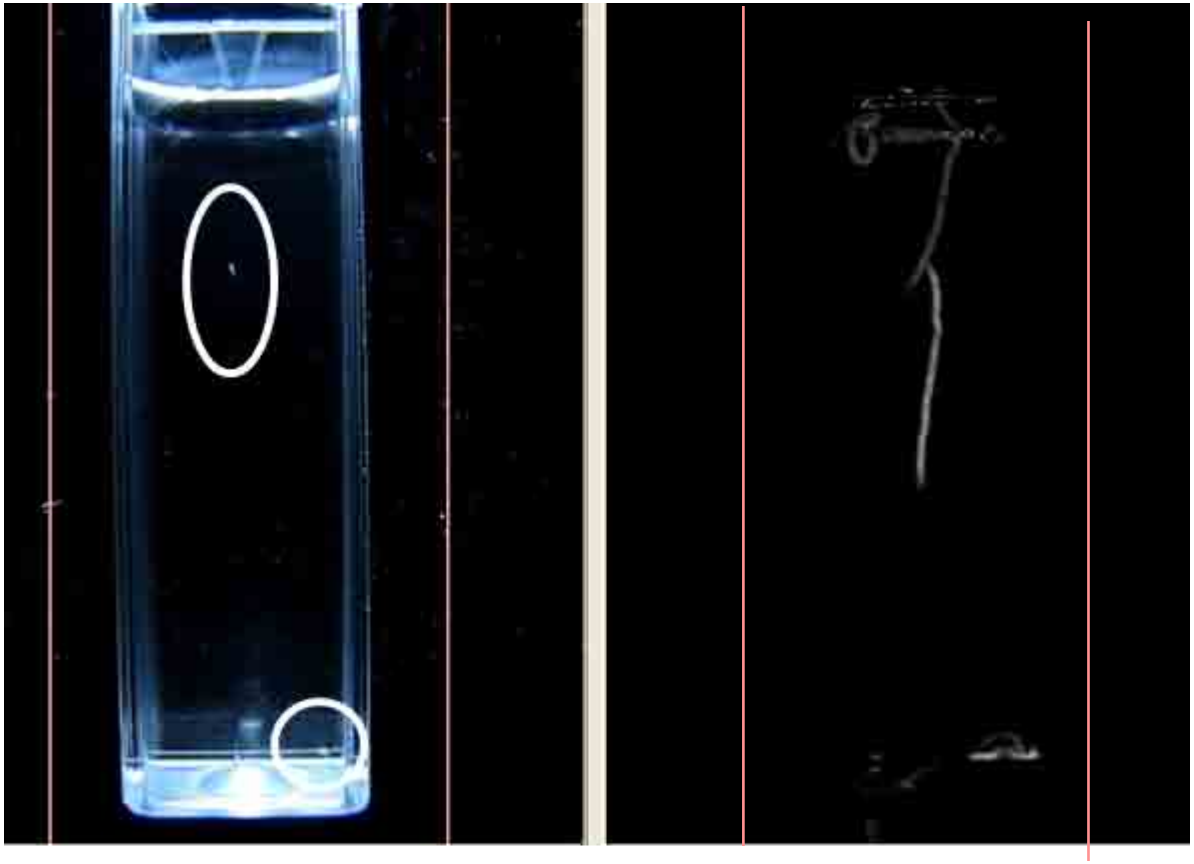
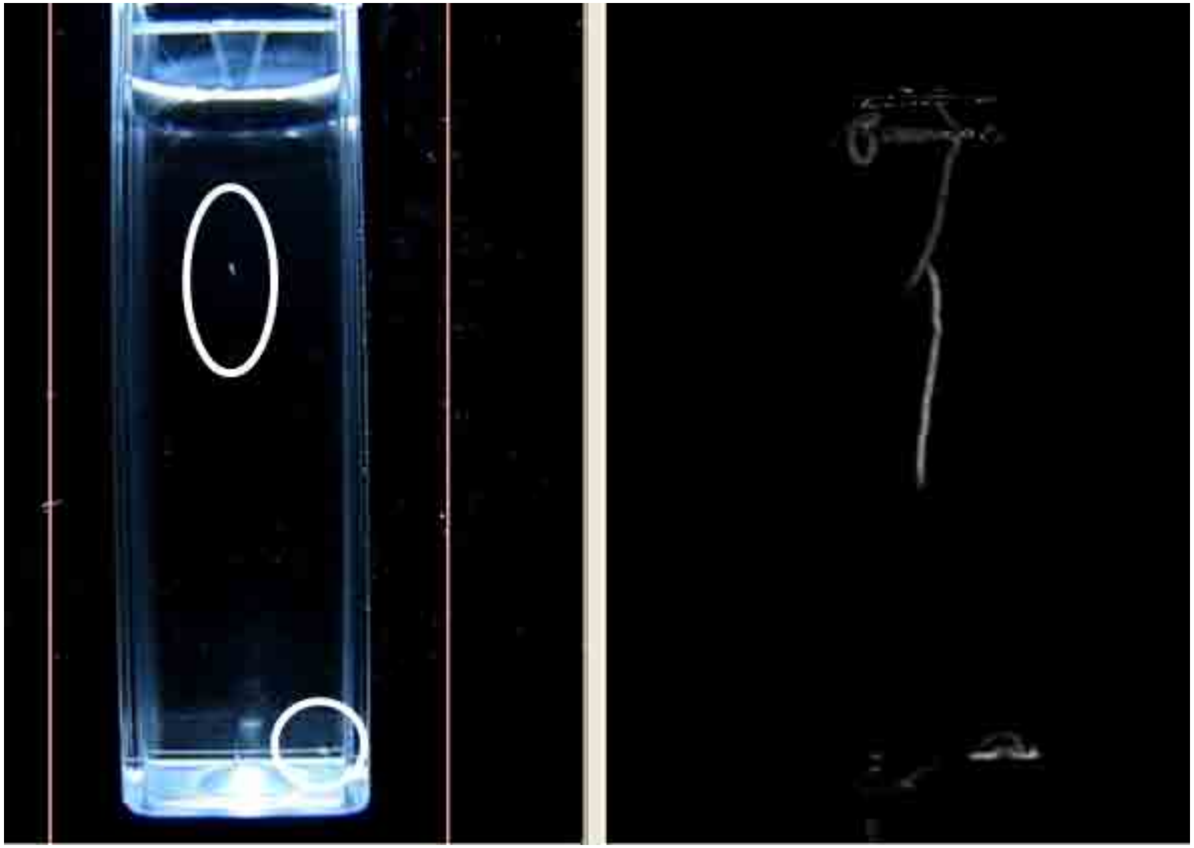


Demo of toxic sample



Simple Software Interface

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Results

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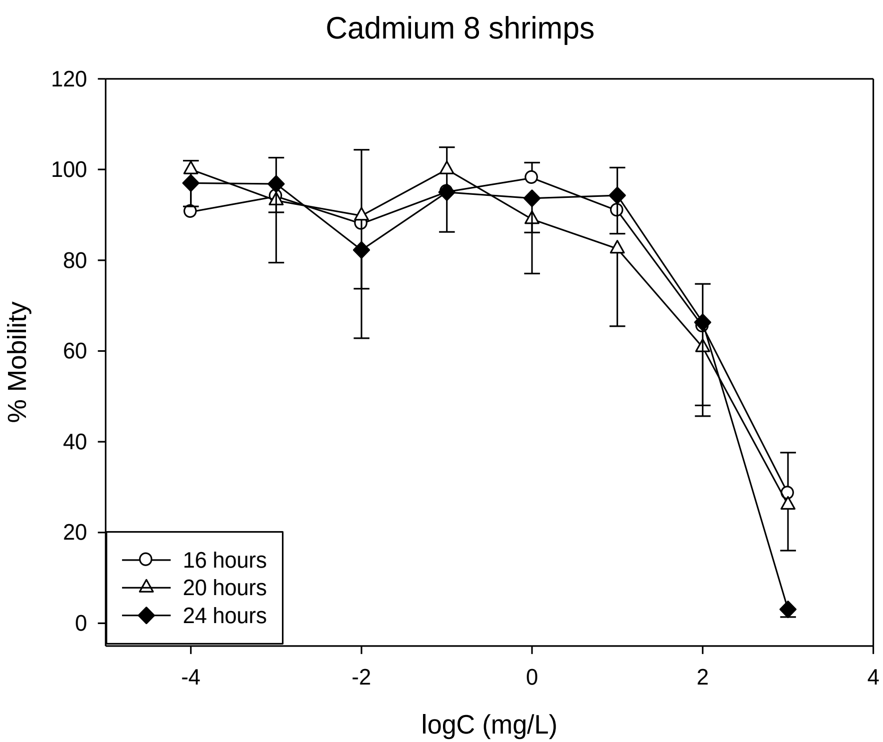
IC_{50} estimated values for the treated compounds according to *Srimpometer device.*

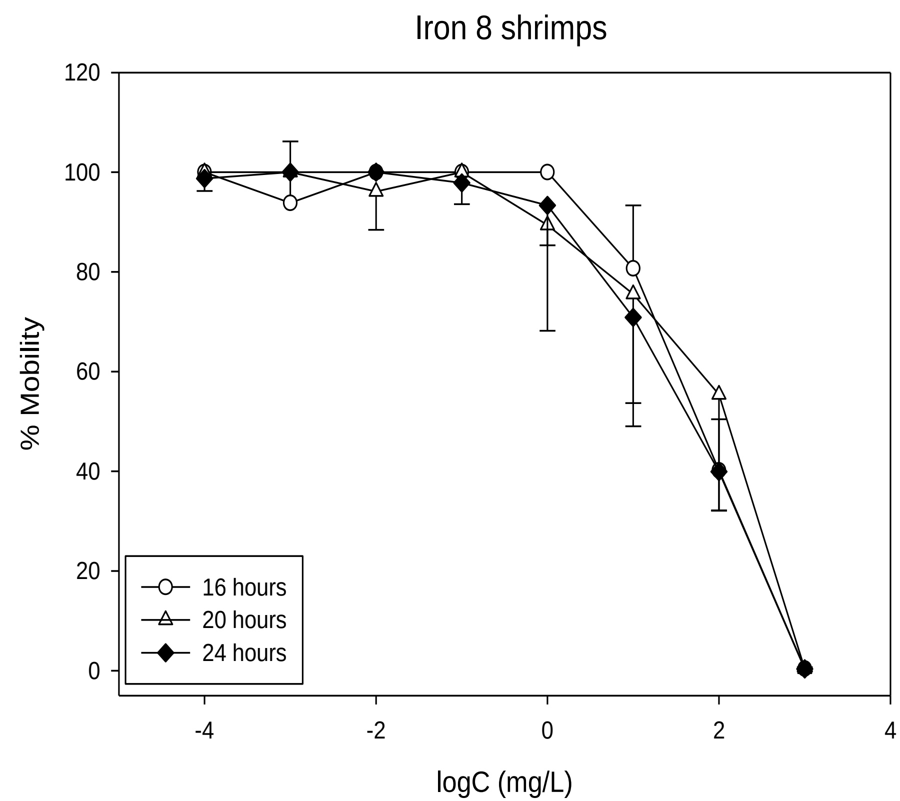
	IC_{50} – 4 nauplii (mg/l)	**Threshold toxicity (mg/l)**	**Microtox® (mg/l)**	**Literature LC_{50} (mg/l)**
Cd^{2+}	54.8	100	-	93.3 -280 (Sarabia et al., 2002)
Cu^{2+}	7.6	1	-	9.5 (Gajbhiye & Hirota, 1990)
Aldicarb	34.8	10	28	(James et al., 2003)*
Colchicine	37.2	10	240	(James et al., 2003)*
Thallium sulphate	34.1	100	240	(James et al., 2003)*

* EPA_ETV official report

Results

No significantly different results among time intervals tested for all compounds analysed





Effect of time on the mobility of the nauplii in various concentrations of cadmium and iron ions.

Conclusions

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- Digital image processing allows the use of algorithm for processing images in real time with high precision.
- Applicability to high range of contaminants including herbicides, pharmaceuticals, heavy metals, mixtures of contaminants and wastewater samples.
- Minimised incubation period (from 24 to 16 hours) with high potential for further reduction ⟹ portable to fields
- No need for temperature control ⟹ lower cost
- Early detection

Thank you!

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www.shrimpometer.com