Twinning Project PL2005/IB/EN/03

Seminar on *"Legionella: sampling, monitoring and treatments"*

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Use of chlorine dioxide in Legionella disinfection

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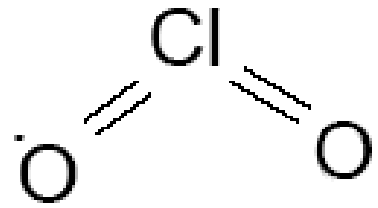
Chlorine dioxide

Chemical-physical properties:

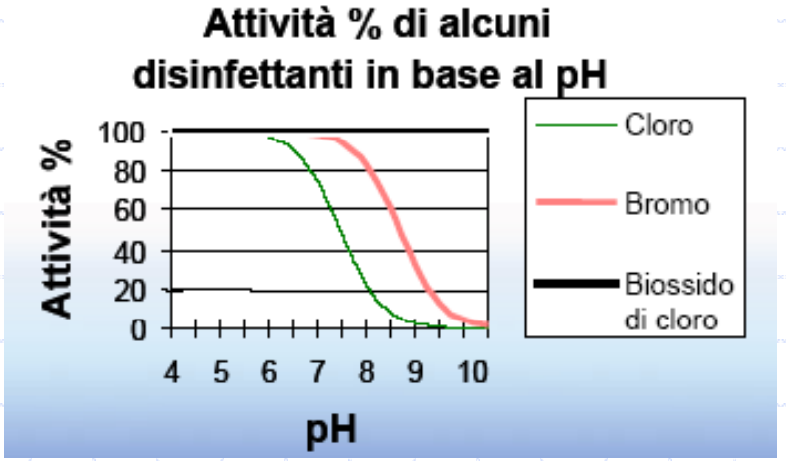
- Chlorine dioxide particle consists of one chlorine atom and two oxygen atoms:



- Boiling temperature : 11°C
- High redox potential:

$$ClO_2 + e^- \rightarrow ClO_2^- \qquad E_0 = 0{,}95\ V$$

- Very good solubility in water (higher than for chlorine and ozone)
- No pH sensitivity:



Chlorine dioxide

- **Production**

Yellow-green gas, cannot be stored or compressed. Produced as a result of the following reaction:

$$4HCl + 5NaClO_2 \rightarrow 4ClO_2 + 5NaCl + 2H_2O$$

- **Form:**

solution 0,2-2% (2-20 g/l)

- **Applied products:**

$NaClO_2$: diluted solution 25%
concentrated solution 7,5%
HCl: diluted solution 9%
concentrated solution 33%.

Chlorine dioxide

Enables constant disinfection leaving small quantities of residual chlorine and keeping its suitability of water for drinking

Limits for drinking water

- **WHO, Guidelines for Drinking-Water Quality, 3rd edition:**

Acceptable recommended value for ClO2 has not been established as it decomposes to chlorites and also because provisionary acceptable recommended value for chlorines is a sufficient protection against potential toxicity of ClO_2

Chlorites i chlorates - 0.7 mg/l (disinfection with $Cl0_2$)
"This recommended acceptable value was establisehd as provisionary because the use of chlorine dioxide as disinfectant can cause that the recommended acceptable value forchlorites will be exceeded and the entailing difficulties keeping recommended acceptable value should not be a reason for deterioration of water disinfection efficiency"
WHO 2005 Chlorite and Chlorate in Drinking Water
WHO/SDE/WSH/05.08/86

Chlorine dioxide

Limits for drinking water

- **EPA (United States Environmental Protection Agency): max. 0,8 mg/l ClO_2, max. 1,0 mg/l chlorite;**
- **HSC (Health & Safety Commission GB): max. 0,5 mg/l ClO_2 + chlorite + chlorate;**
- **Guidelines on drinking water - Germany: max. Dose ClO_2: 0,4 mg/l, max. residue: ClO_2: 0,2 mg/l, max. Chlorite residue : 0,2 mg/l;**
- **Italy (D.Lgs. 31-2001): max. Chlorite residue: 0,7 mg/l.**

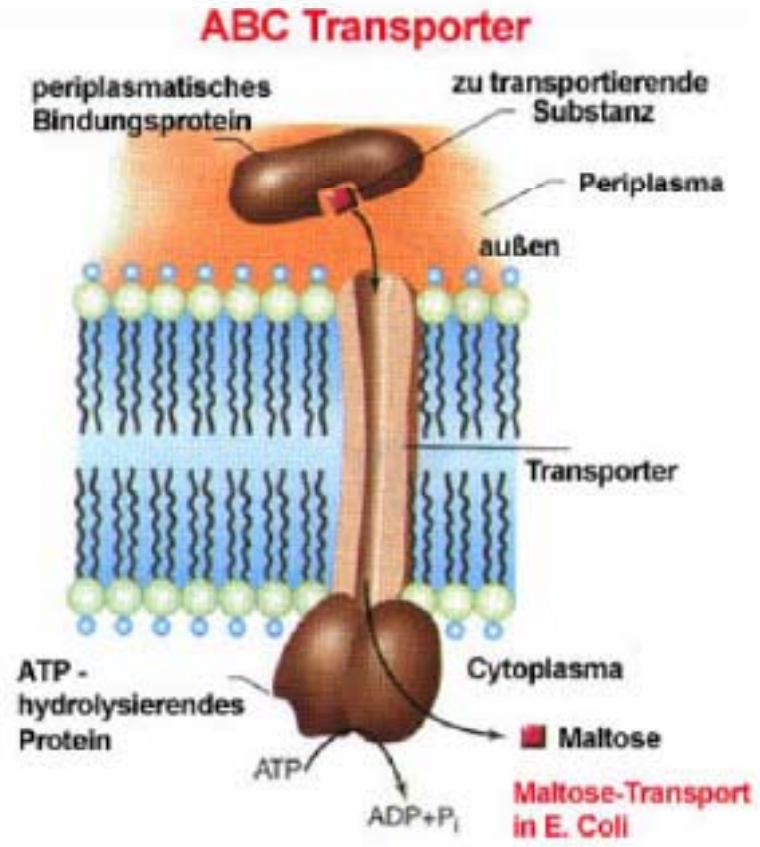
Chlorine dioxide

Inactivation of bacteria and viruses

Higher selectivity of action in comparison with other oxidants and is appropriate for inactivation of bacteria and viruses

Action on cell level on nutrients supply mechanisms (maltose)

Break of bacteria and virus foodchain – prevents from multiplication.



Chlorine dioxide

Inactivation of bacteria and viruses

A very low value CxT(product of concentration and contact time)

Micro-organism	Inactivation Rate	Chlorine	Chlorine-dioxid	Ozone	UV
	(%)	c x t (ppm x min)	c x t (ppm x min)	c x t (ppm x min)	J/m²
Cryptosporidium parvum	99.9	1440	> 120	> 5	100-200 (99.99 %)
Giardia Lamblia	99.9	104-122	23	1.4	100-200 (99.99 %)
Escherichia Coli	> 99.99	3-4	1.2	0.012 - 0.4	128
Aspergillus niger	10^5		1.6*		
Bacillus subtilis	10^4		>>5*	>>5*	
Sacch. cerevisiae			0.8*	0.5*	

*z 100 ppm of humidifier

T = 20 – 30°C

Chlorine dioxide

Inactivation of bacteria and viruses

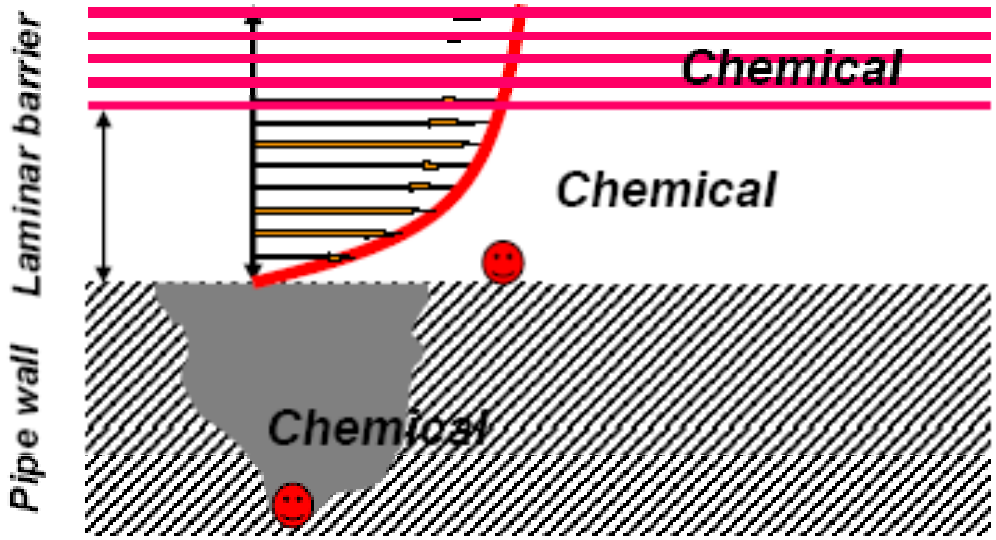
Even at low concentrations (0,2-0,4 mg/l) for a short contact tume reduction of pathogens by 4-5 log (reduction in log scale)

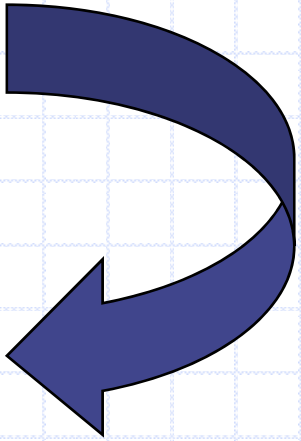
Microorganismo	ppm ClO2	Tempo contatto	Inattivaz. in %
Staphylococ. aureus	1	60 sec.	99.999
Escherichia coli	0.15	5 min.	99.9
Escherichia coli	0.25	60 sec.	> 99.999
Streptococcus faecali	1	15 sec.	> 99.999
Lactobacillus brevis	0.15	5 min.	99.9
Lactobacillus brevis	1	5 min.	> 99.999
Pseudomonas aerog.	1	60 sec.	> 99.999

Legionella elimination

Advantages:

- High disinfection capacity independently of pH (od 4 do 10);
- High microbiological stability of water due to long-term control (> 48h);
- Minimum corrosion risk (used in low concentrations);
- Efficient doses: 0.2 - 0.4 mg/l; in many countries ClO_2 dose for drinking water treatment is about: 0.4 -1.0 mg/l);
- High efficiency in biofilm elimination.





Legionella elimination

Advantages:

- Limited by-products creation:
  - does not create chlorides (corrosion!!!)
  - does not react with ammonia (i.e.: chloroamine)
  - practically ktycznie does not create THMs , (i.e. chloroform) does not create chlorophenoles and i AOX.

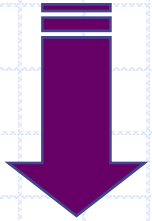
(Prof. Sontheimer, 1980)

Addition of	$CHCl_3$ (ppb)	$CHBrCl_2$ (ppb)	$CHBr_2Cl$ (ppb)	$CHBr_3$ (ppb)	THM (ppb)
Chlorine 1 ppm	0.6	1.4	9.4	53.8	65.2
Chlorine 5 ppm	1.7	5.0	30.6	90.6	127.9
ClO_2 1 ppm	0.2	< 0.1	< 0.1	0.4	0.8
ClO_2 5 ppm	0.1	0.1	0.1	1.9	2.2

Legionella elimination

Disadvantages:

- **Higher cost in comparison with chlorine and ionisation.**
- **Chemical health risk – cration of ClO_2**
- **Impossible to use in copper pipings**



According to the current scientific and technical knowledge, and on the basis of economic analyses, it os considered that chlorine dioxine is a compromise solution allowing efficient implementation of the program of elimination and limitation of Legionella presence in water installations.

Legionella elimination with the use of chlorine dioxide

Installation for flow intensity >25 m^3/h

Tipo	max. Produzione (g/h)
CDVb 15	15
CDVb 35	46
CDVb 60	66
CDVb 120	130
CDVb 220	225
CDVa 400	400
CDVa 600	600
CDVa 2000	2000

- **Relatively uncomplicted installation**
- **Uncomplicated set for monitoring and control of production of ClO_2**
- **Can be used for cold and hot water circulation.**

Legionella elimination with the use of chlorine dioxide

Installation for flow intensity < 25 m3/h

- Generator: for disinfection of water contaminated with Legionella.

  Integrated dispensing pump ClO_2 :

  capacity: 0 –5 g/h
- Porotion steering due to the non-constant operation mode
- Diluted products
- Concentration ClO_2: 2 g/l (0,2 %):

  no hazards for operators
- Perfect stability (-15% after 3 days)

Case study No. 1 (2003)

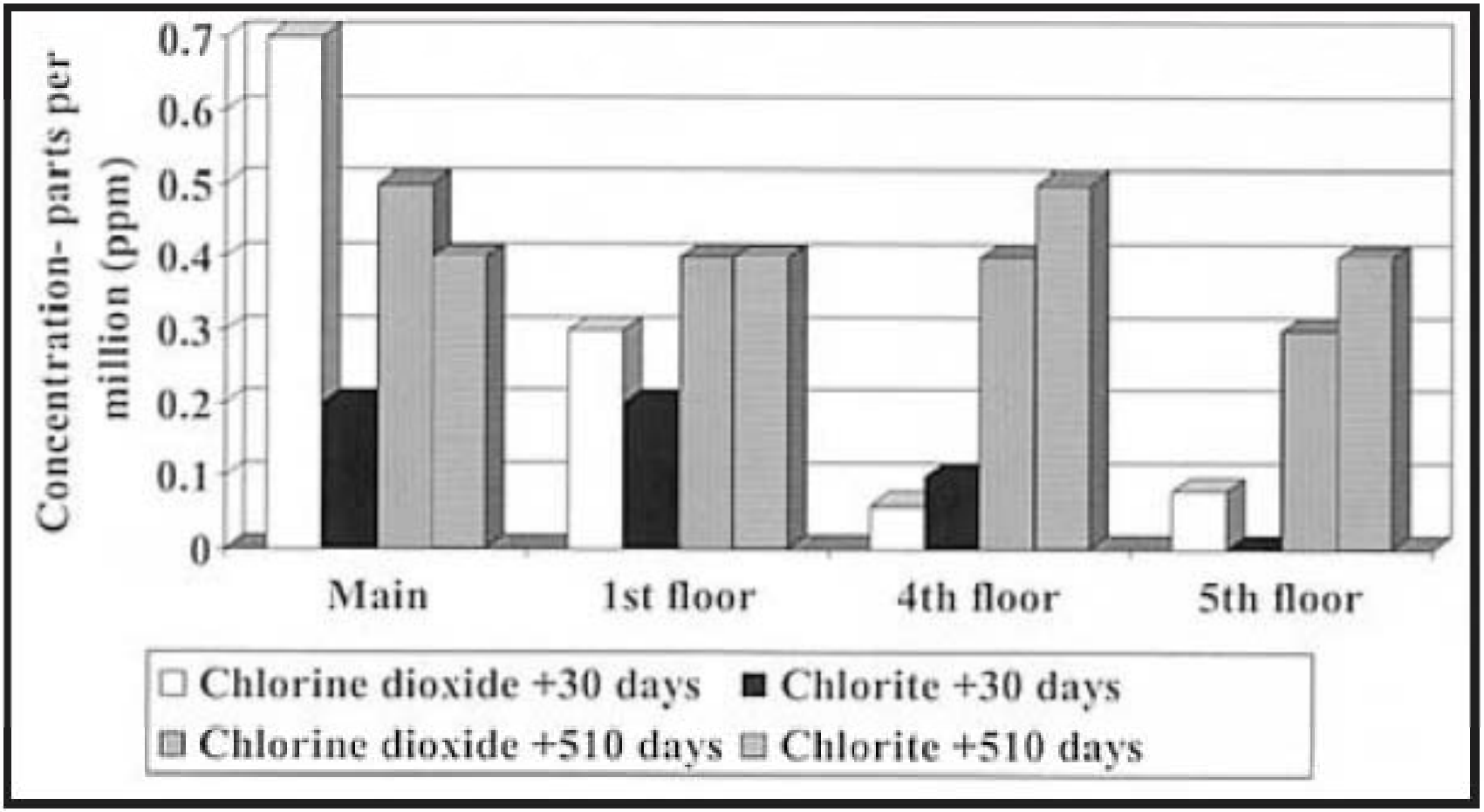
A 17-month evaluation of a chlorine dioxide water treatment system to control Legionella species in a hospital water supply

OBJECTIVE: To assess the safety and efficacy of a chlorine dioxide water treatment system in controlling *Legionella* in a hospital water supply.

DESIGN: For 17 months following installation of the system, we performed regular water cultures throughout the building, assessed chlorine dioxide and chlorite levels, and monitored metal corrosion.

Case study No. 1 (2003)

A 17-month evaluation of a chlorine dioxide water treatment system to control Legionella species in a hospital water supply



Concentrations of chlorine dioxide and chlorite at various locations throughout the building after 30 and 510 days of operation of the system. At 30 days, levels were higher at the main than on the first and upper floors; however, this difference had decreased markedly by day 510.

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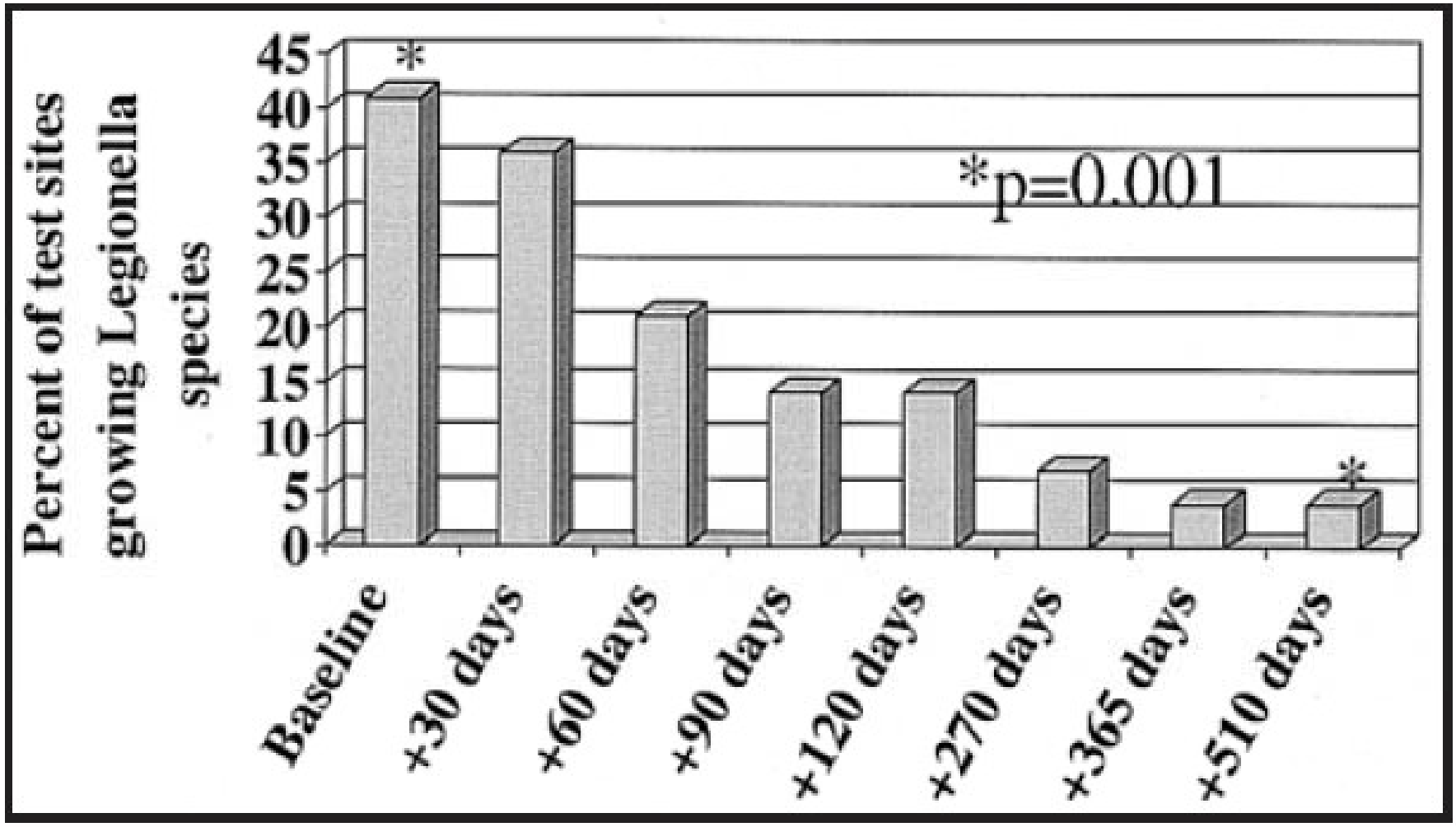


Percent of test sites that grew Legionella species during the evaluation of the chlorine dioxide system. The decrease from 41% to 4% was statistically significant (P =0.001).

Case study No. 1 (2003)

A 17-month evaluation of a chlorine dioxide water treatment system to control Legionella species in a hospital water supply

RESULTS

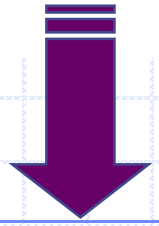
- Sites that grew *Legionella* species decreased from 41% at baseline to 4% (P = .001). *L. anisa* was the only species recovered and it was found in samples of both hot and cold water. Results indicate that operation of a chlorine dioxide system effectively removed *Legionella* species from a hospital water supply.
- The chlorination system was safe, as levels of chlorine dioxide and chlorite were below legal levels.
- The system did not appear to cause increased corrosion of copper pipes.
- Results indicate that chlorine dioxide may hold promise as a solution to the problem of *Legionella* contamination of hospital water supplies.

Case study No. 2

Ten years experience with Chlorine Dioxide in the control of Legionella pneumophila in a hospital water supply.

Legionella: 1984 -89

- 19 cases of hospital acquired legionellosis
- 16 cases in outbreak of 1985
- associated with cooling tower
- 3 other sporadic cases in Old Hospital
- Lp1, Lp3 & Lp6



Chlorine Dioxide disinfection

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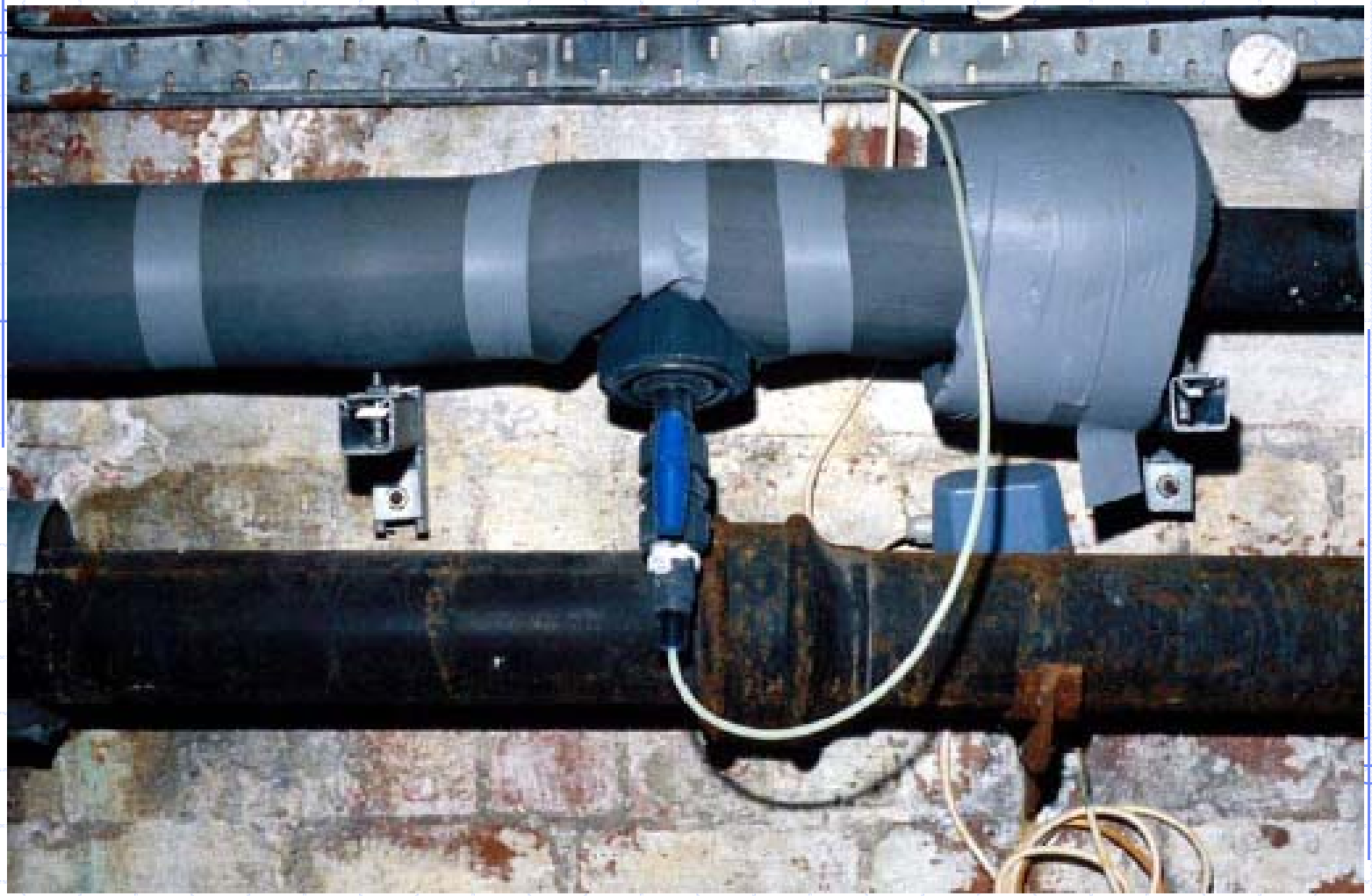

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Case study No. 2

CONCLUSIONS

- Over a 10 year period we have shown that 0.5 mg/l ClO_2 is extremely effective in controlling planktonic *Legionella pneumophila*
- In a complicated, old water system
- Where the water is soft with a high pH
- Full effect may take up to 6 weeks after continuous dosing commences
- It is well tolerated by both staff & patients
- There has been no corrosion failures

Case study No. 2

CONCLUSIONS

- However it is less effective where significant engineering problems exist e.g. long pipe-runs, or stagnation
- though the presence of Lp1, low ClO_2, *L.anisa* &/or high TVCs, points to the presence of such problems
- so it is not a panacea, more a useful adjunct to good engineering practices (e.g. use of double-check valves -allowing migration between hot & cold water systems, ecc.)

Thank you for your attention!