The effect of Water Quality on Feedlot Performance and Compliance Monitoring

James Meyer

Research Background

- Primary field:

  Physiology

- Specialist Areas:

  Environmental Toxicology
  Hazard and Risk Assessments
  Endocrine Disruption

Main Current Focus

- Research:

  Development of SA National Risk-based Water Quality Guidelines

  Manual for Endocrine Disrupting Chemicals

Main Current Focus

- Additional:

  Sentinel monitoring for Community Health
  (broilers & porcine)
  Assessment of water quality treatments
  (site-specific & commercial)
  Compliance, Monitoring and Enforcement
  (DWS & DEA)
  Wastewater treatment and use

Research Project Status

- SA National Risk-based Water Quality Guidelines
  - Phase 2: Commenced
  - Irrigation Use – current WRC Project
- Manual for Endocrine Disrupting Chemicals
  - Volumes 1 – 5 Complete
  - WRC Project No: K5/1915: Volume 4: Monitoring and Assessment
  - WRC Project No: K5/1956: Agricultural Chemical Impact

Presentation Outline

Standard Approach

Brief Introduction to Water Quality Guidelines

Compliance Monitoring

Water Quality – A B Cs

A

Achieve Acceptable Risk Levels

B

Ensure no Process compromises quality

C

Compare Correct Performance Results!

Analytical Observations Required

Full Inorganic Chemistry:

Macro elements & Trace elements (ICP-MS)

Physico-Chemical Properties

COD; Suspended Solids; Ammonia; Surfactants

Microbiological Indicator Organisms

TBC; TCC; Faecal coliforms; *E. Coli*

This Monitoring information is used for both:

Water Quality Assessments

&

Demonstrating Compliance

You must monitor
controlled water use activities:

Water Quality Results thus needed for:

-Source

-Wastewater

-Any relevant water resource receptors

Wastewater generated or treated complies with the:

GN 665 definition of:

Biodegradable Industrial Wastewater

(CAFO)

You may as per the GN 665:

- Irrigate to land

- Dispose for the purposes of storage

(Section 21 e and 21 g activities)

Wastewater generated or treated must comply with:

GN 665 Precautionary Practices

WRC Guidelines = Solid & Liquid Fractions

GN 921 = delisted:

Manure, Wastewater, Sewage, Effluent

Why be concerned about water quality?

Water Quantity
is an obvious prerequisite input.

Water
is the
most important nutrient
for beef cattle.

Water Intake and Feed Intake
are significantly correlated.

$R^2 = 0.43$ ($P<0.01$)

(McDonald 2012)

No shelter provision

$R^2 = 0.79$ ($P<0.01$)

(McDonald 2012)

Maximum Temperature

Best variable to predict WI

(McDonald 2012)

ADG a function of WI

(Brew et al., 2009)

Water Feed Ratio = 5.81 l/kg/d in sows – constant for first 60 days of pregnancy

(Kruse et al., 2011)

Unexplained variation in RFI
may be primarily due to thermoregulatory factors….water intake involved

(Arthur & Herd, 2008)

WI (l/d)

BW (kg)	T (ºC)		
	10	21	32
180	16	22	36
270	25	35	57
360	30	47	78

Growing steers 23% more weight gain from well water compared to pond water

(Brew et al., 2009)

Physiological reality:

cattle are in a continual state of dehydration

and not particularly good
at handling
water deprivation challenges

Commercial reality:

Profitability margins.

Commercial reality:

Performance and efficiency
can be improved by
managing water quality better.

Water quality does not have to remain a fixed variable.

Mitigating effects and improving water quality are receiving increasingly successful attention in commercial intensive animal production

Commercial reality:

Corporate Liability,

ensuring rights to access of both sufficient water quantity and quality,

and Lawfulness of Water Use

are all increasingly relevant topics.

Commercial reality:

Without Compliance Monitoring

you may not only face significant fines,

but also loose the rights of both
access to water use
and
water of the required quality.

Why be concerned about water quality?

#1: Adverse Effects

#2: Water Quality Resource Management

#3: Emerging Topics

#1: Adverse Health Effects

Nitrate = potentially fatal methemoglobinemia

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Fluoride = enamel hypoplasia


4214
AFIP

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Sulphate = diarrhoea & trace element deficiencies

#1: Adverse Health Effects

Nitrate = potentially fatal methemoglobinemia

Fluoride = enamel hypoplasia

Sulphate = diarrhoea & trace element deficiencies

TDS = lowered water and feed intakes

Classic

toxicological approach

has revealed abundant evidence of clearly defined

cause and effect relationships

between

Exposure and Adverse Health Effects.

Table 2. Water Quality Guidelines for Livestock[1]

Item	Maximum Recommended Limit (ppm)	Item	Maximum Recommended Limit (ppm)
Major ions		Cobalt	1.00
Calcium	1000	Copper	5.00
Nitrate + nitrite	100	Fluoride	2.00
Nitrite alone	10	Iron	
Sulphate	1000	Lead	0.10
TDS	3000	Manganese	
Heavy metals and trace ions		Mercury	0.003
Aluminium	5.00	Molybdenum	0.50
Arsenic	0.50	Nickel	1.00
Beryllium	0.10	Selenium	0.05
Boron	5.00	Uranium	0.02
Cadium	0.02	Vanadium	0.10
Chromium	1.00	Zinc	50.00

However:

Adverse Health Effects

are not the only

Type of Effects

that occur.

Confined Animal Feeding Operations:

Palatability

Confined Animal Feeding Operations:

Palatability

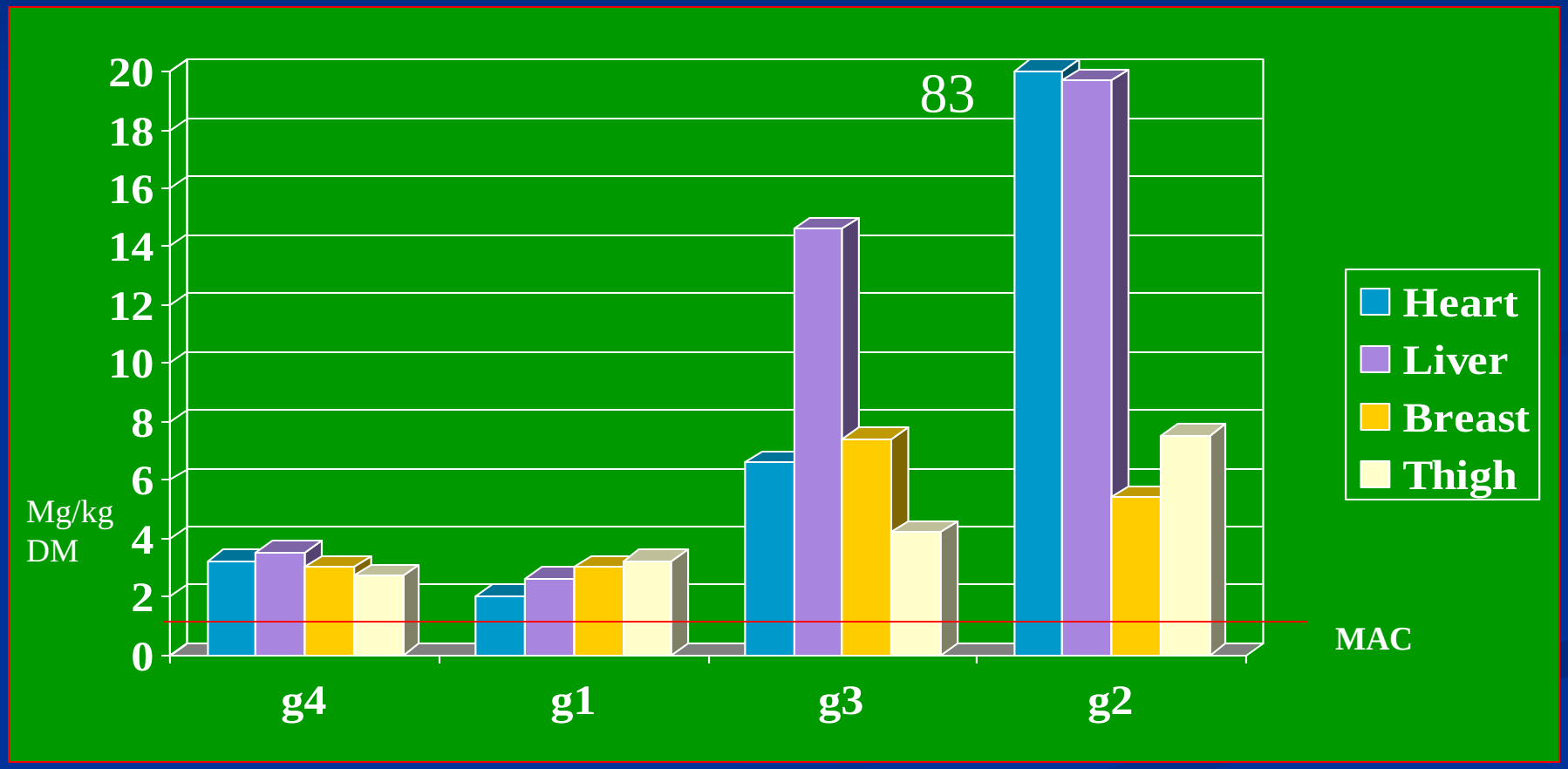
Product Quality

Confined Animal Feeding Operations:

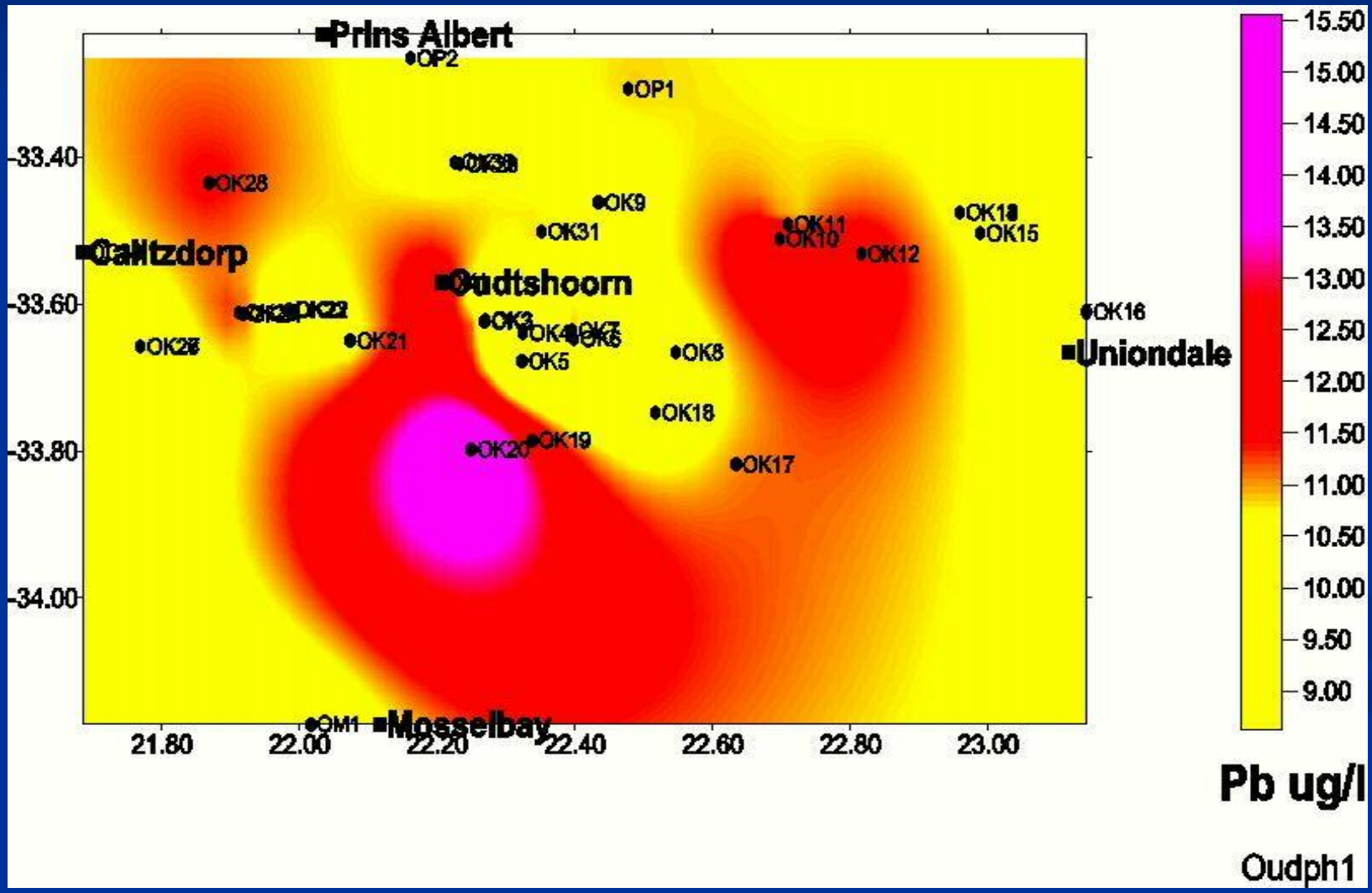
Palatability

Product Quality:
- export requirements
- consumer health concerns

Lead observed in poultry tissues obtained from PPU – Limpopo Province



Subclinical: Product quality
Export Requirements (MAC)



Confined Animal Feeding Operations:

Palatability
Product Quality

Water Distribution System

Confined Animal Feeding Operations:

Palatability
Product Quality
Water Distribution System

Environmental

Confined Animal Feeding Operations:

"Runoff from feedlots causes pollution issues in receiving water resource environments"

Ammonia, Potassium, Nitrate, Phosphate, trace metals…

(Rahman et al., 2013)

RSA – WRC K5/1686/1

Downstream water samples collected 2007/8 = positive:

- Reporter gene assays:

Recombinant Yeast Oestrogen screen assay

- Competitive Oestrogen Receptor binding assay:

hER

Types of Effects:

Referred to as

Norms

Used to Assess

the

Fitness for Use

Fundamentally:

Central Point of Departure

relates to the

water quality constituent

Managing Water Quality

Can I detect the substance?
Does the substance detected demonstrate toxicity?
Is the context of exposure capable of being hazardous?
Is the risk high or low?
What are the costs of mitigation or treatment?
What are the legal considerations that apply?

FUNDAMENTAL APPROACH - EIA

- Sources, Pathways, Receptors
- Management

Environmental Toxicology

- Toxicology terms:
  - Toxicity = qualitative
  - Hazard = qualitative and quantitative
  - Risk = expected frequency of AE (not necessarily AHE)
- Potentially Hazardous Constituent
- Constituent of Concern

RSA situation – NDA Survey of groundwater (n = 507)

WQC	Median (mg/L)	Guideline (mg/L)	Maximum (mg/L))
As	0.02	0.01	1.056
Br	0.216	0.01	18.426
F	1.7	0.7	16.69
Pb	0.035	0.01	5.411
NO3	115	44	1503
Se	0.036	0.02	3.069
V	0.545	0.1	0.86
Cr	0.33	0.05	0.667

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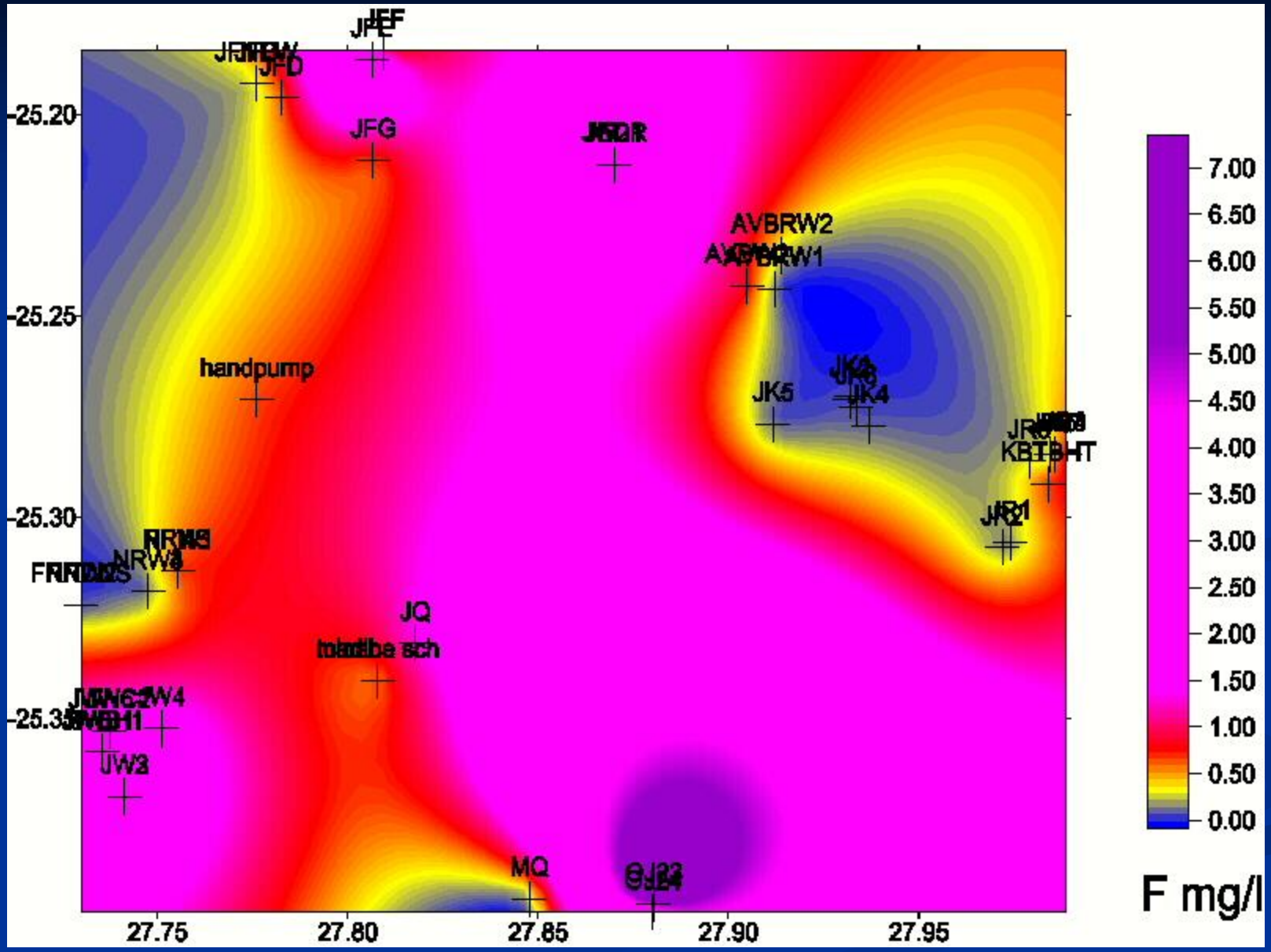

JFG
AVBRW2
handpump
JK5
JK4
JQ
MQ
-25.20
-25.25
-25.30
27.75
27.80
27.85
27.90
27.95
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
F mg/l

Managing Water Quality

Remember, you can

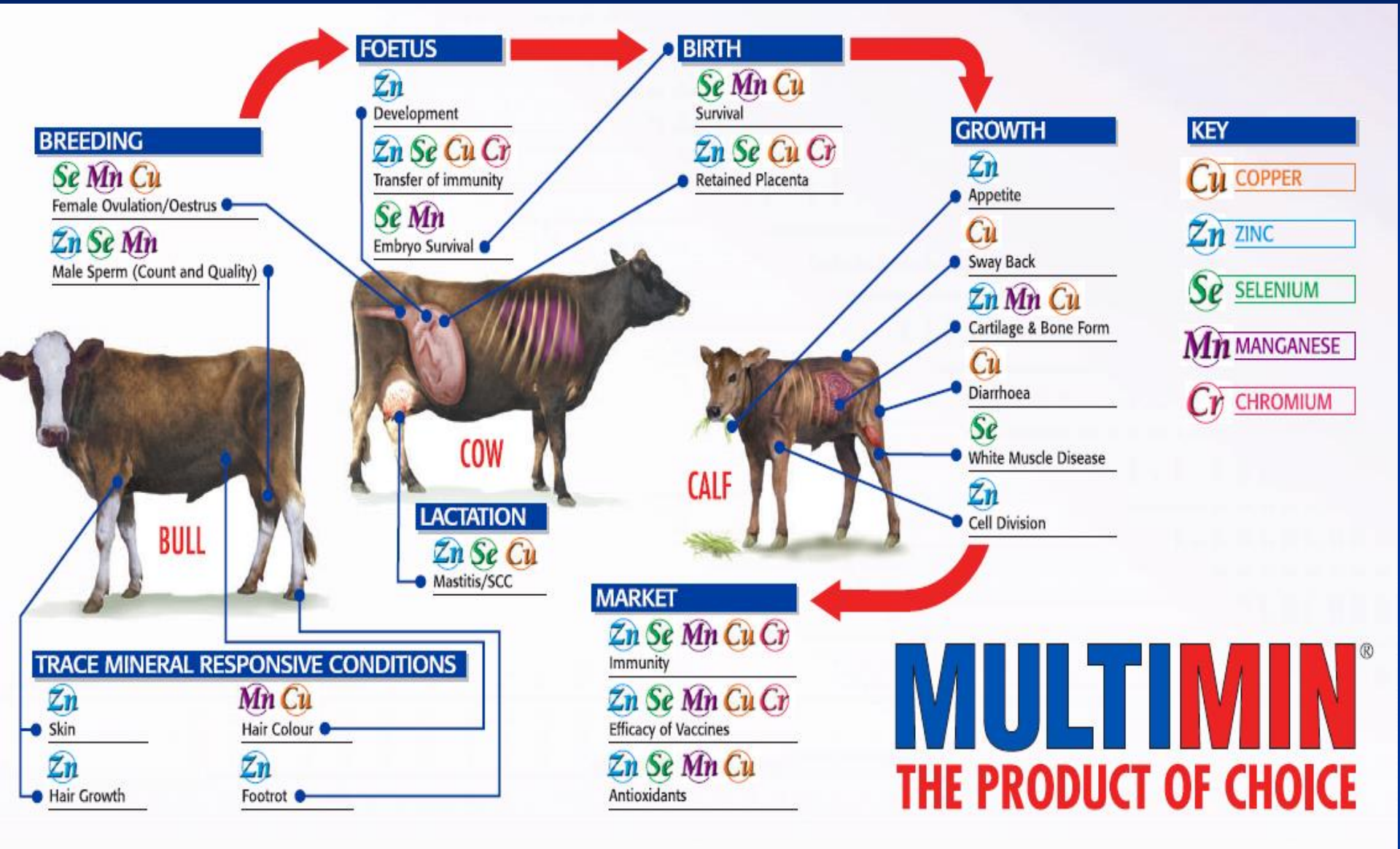
Manipulate

Water Quality

And

Mitigate Adverse Effects

TRACE MINERALS IN THE LIFE CYCLE



MULTIMIN®

THE PRODUCT OF CHOICE

Multimin

- Enhance the trace mineral dependant functions in the production cycle of feedlot cattle.

- It is important that Multimin should not be considered as an alternative to oral supplementation programs (in feed), but as a complementary route to improve immune function and production.

Norm = Health

Water Quality Guideline Ranges:

Fluoride (mg/L):

0 – 0.7 = Ideal

>0.7 -1.0 = Good

1.0 – 1.5 = Marginal

1.5 – 3.5 = Poor

>3.5 = Completely Unacceptable

Norm = Health

Water Quality Guideline Ranges:

Nitrate (mg/L):

0 – 26 = Ideal

>26 -44 = Good

44 - 89 = Marginal

89 - 177 = Poor

>177 = Completely Unacceptable

Beef Cattle

Nitrate (mg/L):

0 – 26 = Ideal

>26 -44 = Good

44 - 89 = Marginal

89 - 177 = Poor

>177 = Completely Unacceptable

Perspective 1:

Nitrate  Toxic Effects

Perspective 1:

Nitrite → Toxic Effects

Take note of the complexities regarding the ability to adapt to nitrate exposure

This is a function of nitrate – nitrite – ammonia rumen pathways.

Perspective 1:

Nitrate → Toxic Effects

↓

Recognised Endocrine Disrupting Chemical

Perspective 1:

Fluoride → Toxic Effects

↓

Recognised Endocrine Disrupting Chemical

To Summarise:

Toxic (Reference Doses)
Carcinogenicity (Slope Factors)
Endocrine Disruption (Bioassays)

EDC – current review

- "Low doses are the most pertinent when exposure occurs to developing organisms. In some cases, these organisms normally have no exposure to some hormones — and exposure to tiny amounts of an endocrine disruptor changes the way these organisms will develop and potentially predispose them to develop a disease later in life.
- ..and it is possible that exceedingly small exposures could lead to endocrine problems later in life."

Wexler, JA (Endocrinologist at Washington Hospital Center, Washington, D.C.)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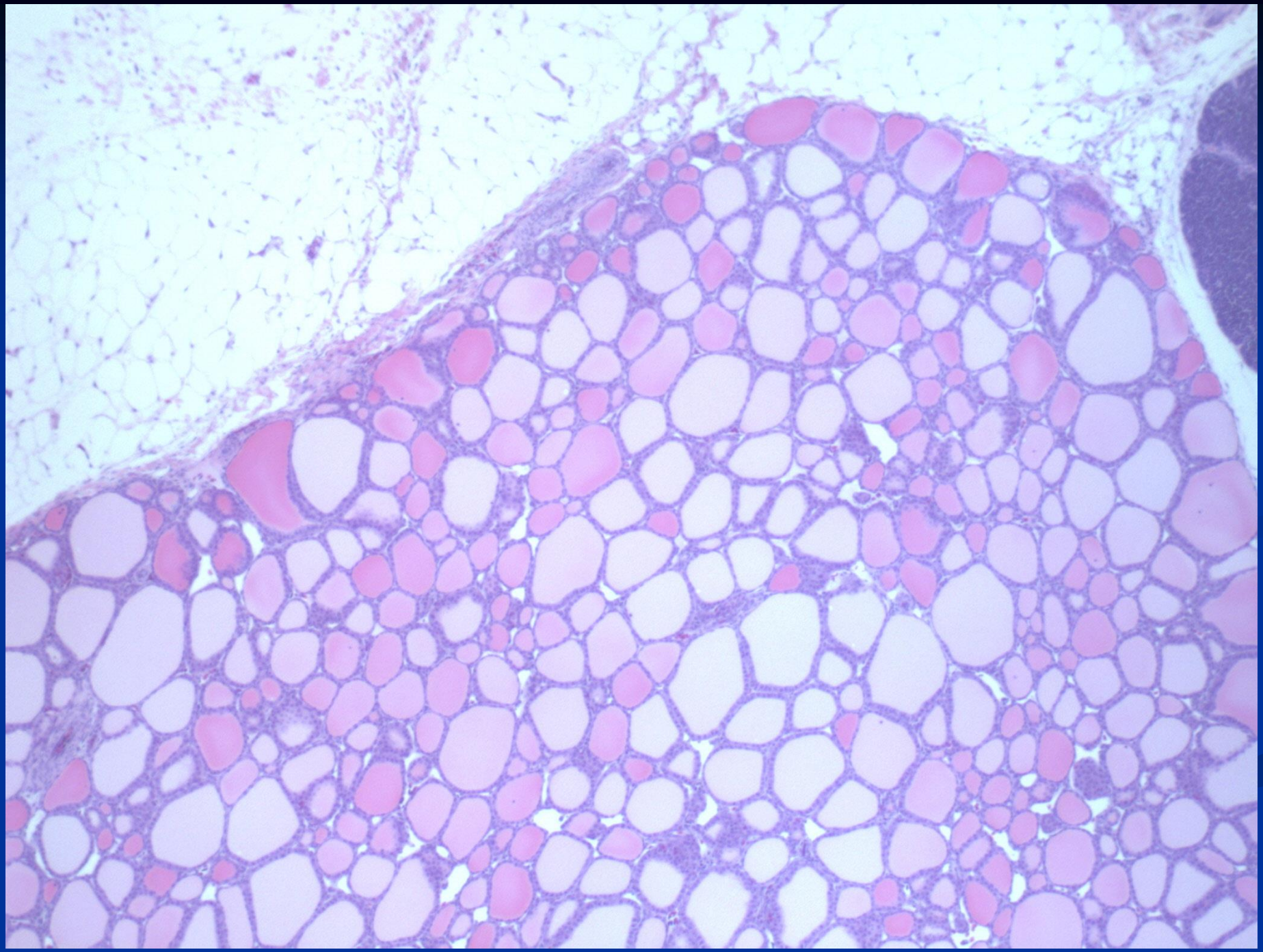
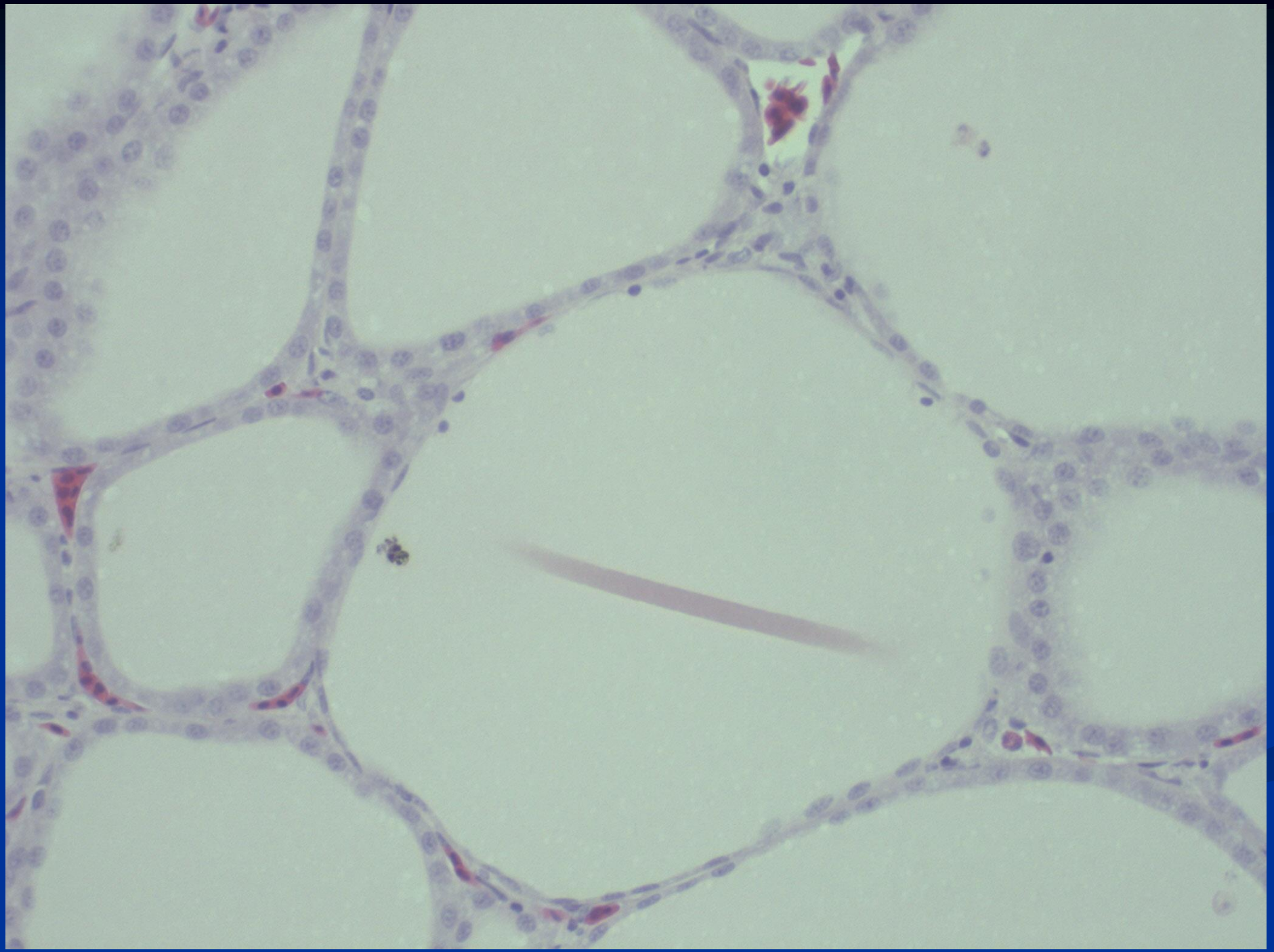
Bromide Perspective

Broiler Sentinel Results: Plasma T4 (thyroxine) nmol/L

	A	B	C
median	3.04	4.945	9.855
sd	(1.696)	(1.625)	(4.09)
P<0.05	a	a	b

Ref 35 days:	Ross 308 =	10.89 ± 0.849
	Non-commercial =	8.906 ± 1.081
Ref 1day:	Ross 308 =	5.933 ± 0.785
	Non-commercial =	5.997 ± 0.123





Bromide Perspective

Broiler Sentinel Results: Plasma T4 (thyroxine) nmol/L

	A	B	C
median	3.04	4.945	9.855
sd	(1.696)	(1.625)	(4.09)
P<0.05	a	a	b
Br (mg/L)	0.393	4.234	0.016

Perspective 1:

Not all Norms are fully understood yet.

Perspective 1:

Increasing evidence suggests the effects of EDCs are
subclinical and significant.

Perspective 1:

Increased awareness for
Induced Deficiencies
due to EDCs is recognised.

Perspective 1:

A precautionary approach is advocated.

Perspective 2:

Different Water Users

are generally present

in the same Catchment.

Water Quality Guidelines:

Must therefore cater for different

Water Quality Requirements

to ensure Constitutional and other legal rights.

Thus:

Controlled Water Use Activities

may not

adversely impact on the

Water Resource.

Water Quality Guidelines:

Do more than just assist the

User

to assess fitness for use.

Water Quality Guidelines:

Are also used to

regulate and manage

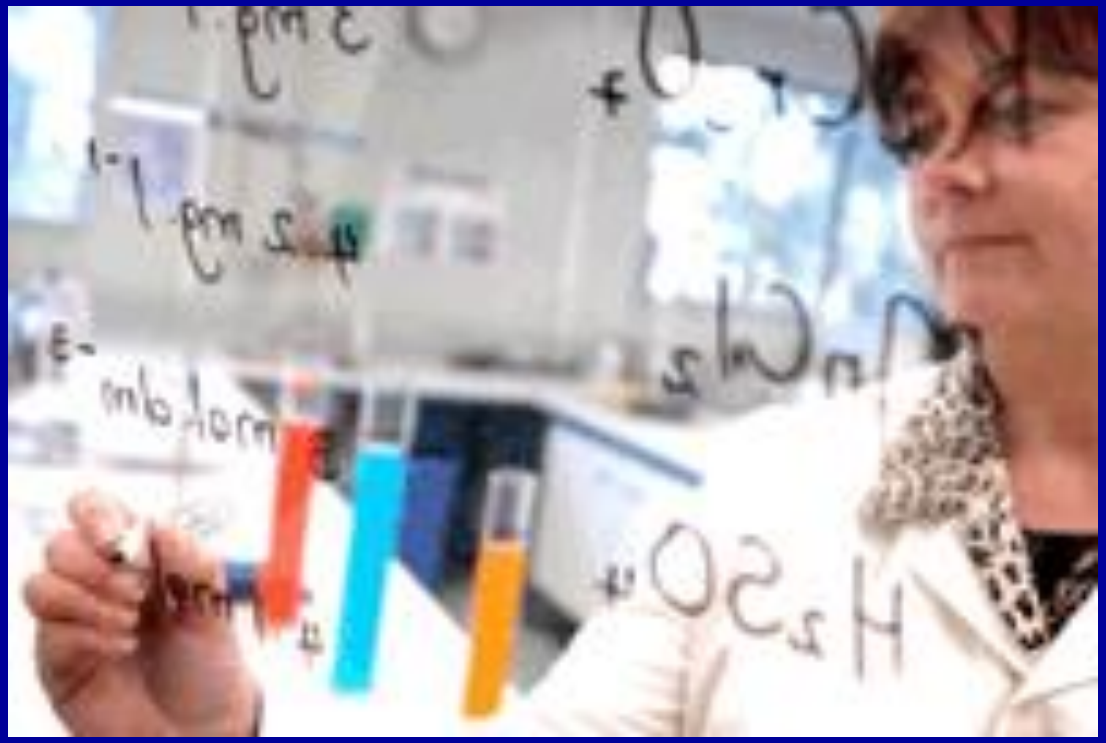
water quantity and quality.

Water Quality Guidelines:

Why not Standards?

Why do they differ so much between countries?

SANS 241: (2011)



SANS 241

Figure 7: Potable Water Quality Compliance for Umgeni Water's Bulk Potable Waterworks 2006-2007

Why the discrepancies between guidelines?

Different constituents and acceptable limits due to:

Failure to adequately describe exposure!

Different water chemistry relevant.

Different treatment processes & capabilities.

TDS (mg/L)	Interpretation	Action
2000 – 3000	Generally Safe. May reduce performance.	Monitor. Caution For Hot Weather.
3000 -5000	Marginal. May reduce performance May reduce health.	Test for Sulphides Monitor.

TDS (mg/L)	Interpretation	Action
<1000	No serious burden	-
1000 - 2000	Temporary diarrhoea.	-
3000 -5000	Should be safe. But, may very possibly cause diarrhoea and be initially refused.	-

SO_4 (mg/L)	Interpretation
<500	Safe
500 - 1500	Trace mineral availability may be reduced. May decrease performance in confined animals. Hot weather a risk factor.

SO_4 (mg/L)	Interpretation
<1000	No serious burden.
1000 - 2000	Associated with neurological impairment. Diarrhoea may occur. May reduce trace mineral status.

Water Quality Guidelines:

Linking a

concentration

to an

effect

is not as simple as it may seem.

Example:

Fluoride: >0.7 mg/L can result in:

enamel hypoplasia
&
skeletal fluorosis

Water Quality Guideline Ranges:

Example: Domestic Use

Fluoride (mg/L):

0 – 0.7

>0.7 -1.0

1.0 – 1.5

1.5 – 3.5

>3.5

Water Quality Guideline Ranges:

Fluoride (mg/L):

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Water Quality Guideline Ranges:

Example: Domestic Use

Fluoride (mg/L):

0 – 0.7 = NAE

>0.7 -1.0 = AE Unlikely

1.0 – 1.5 = Marginal Risk to Sensitive UG

1.5 – 3.5 = Significant AE in most UG

>3.5 = Completely Unacceptable

Target Water Quality Guideline Range?

Fluoride (mg/L):

0 – 0.7 = Ideal

Target Water Quality Guideline Range?

Fluoride (mg/L):

>0.7 -1.0 = Good

Target Water Quality Guideline Range?

Fluoride (mg/L):

1.0 – 1.5 = Marginal

The VALUE chosen as an Upper Limit may actually have more to do with

analytical detection

and

treatment efficacy

than effects on

feedlot performance

Interpretation of Analytical Result

F = 2 mg/l

Interpretation of Analytical Result

F = 2 mg/l

Fluoride is a chronic cumulative toxin.

Interpretation of Analytical Result

F = 2 mg/l

Essentiality has also been demonstrated.

Interpretation of Analytical Result

F = 2 mg/l

Adverse effects are a function of multiple variables.

Assessment

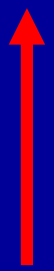
AHE =

f (Conc. * Dose ingestion) * risk factors

Assessment

AHE =

f (Conc. * Dose ingestion) * risk factors



WI (l/d)

BW (kg)	T (ºC)		
	10	21	32
180	16	22	36
270	25	35	57
360	30	47	78

The damage is caused to ameloblasts and odontoblasts during developmental stages.

Erupted teeth are not affected.

Duration of exposure is critical.

Sensitive User Group relevant?

Fluoride at 2 mg/l for Feedlot Cattle

is unlikely to

result in significant adverse health effects

but remains a

potentially hazardous chemical constituent.

Potentially hazardous chemical constituent

due to

intake variation

and

not yet fully described

endocrine disrupting effects

Thus, the correct assessment must take into account site-specific factors.

Failing to do this dictates that a more conservative approach will be followed.

As most of our water resources may not fully comply with the NAE ranges, the development of Risk-based Water Quality Guidelines is acknowledged as essential to sustainable and realistic water resource management in South Africa.

Managing Water Quality

Guidelines are only the first step.

Site-specific multi-disciplinary approaches are required to:

- manage potential hazards

- mitigate adverse effects

#2: Water Quality Resource Management:

Defined Quality Requirements for Catchment Users (RWQO).

Different Users require
Different Water Quality Constituent Criteria to be met.

Wastewater:

Recent changes to schedules:

NWA – GN 665
NEM:WA – GN 921

Take note of the required Section 21 compliance conditions!

Wastewater:

A Waste Management Licence (WML – DEA) is no longer the required legal condition.

Compliance with the NWA Section 21 activities is required.

Wastewater:

Compliance is required for both wastewater generated and final disposal quality.

Wastewater Compliance:

This includes surface runoff
and
treatment outputs (e.g. liquid fraction)

Wastewater Compliance:

Treatment methods
do not remove
the compliance requirements!

Background: NWA - Relevant Sections

- Entitlement to Use
- Pollution Prevention
- Use of Water:
  - Water Use
  - Permissible Use
  - Transfer of Use
- Existing Lawful Water Uses:
  - Verification of water uses
- Controlled Activities
- Financial Provisions & Offenses

#3: Emerging topics

Carcinogenic effects have been comprehensively described for various constituents and DBPs.

Endocrine Disrupting Effects a key topic internationally (water treatment & inherent).

Examples:

Disinfection byproducts from Chlorination and other disinfection processes.

DISINFECTION – Chlorine Dioxide

Chemistry:

$ClO_2 \rightarrow ClO_2^- + ClO_3^- + Cl^-$

Chlorine dioxide → chlorite + chlorate + chloride

1 mg/L → 0.7 mg/L chlorite

1 mg/L → < 0.3 mg/L chlorate

1 mg/L → < 0.1 mg/L chloride

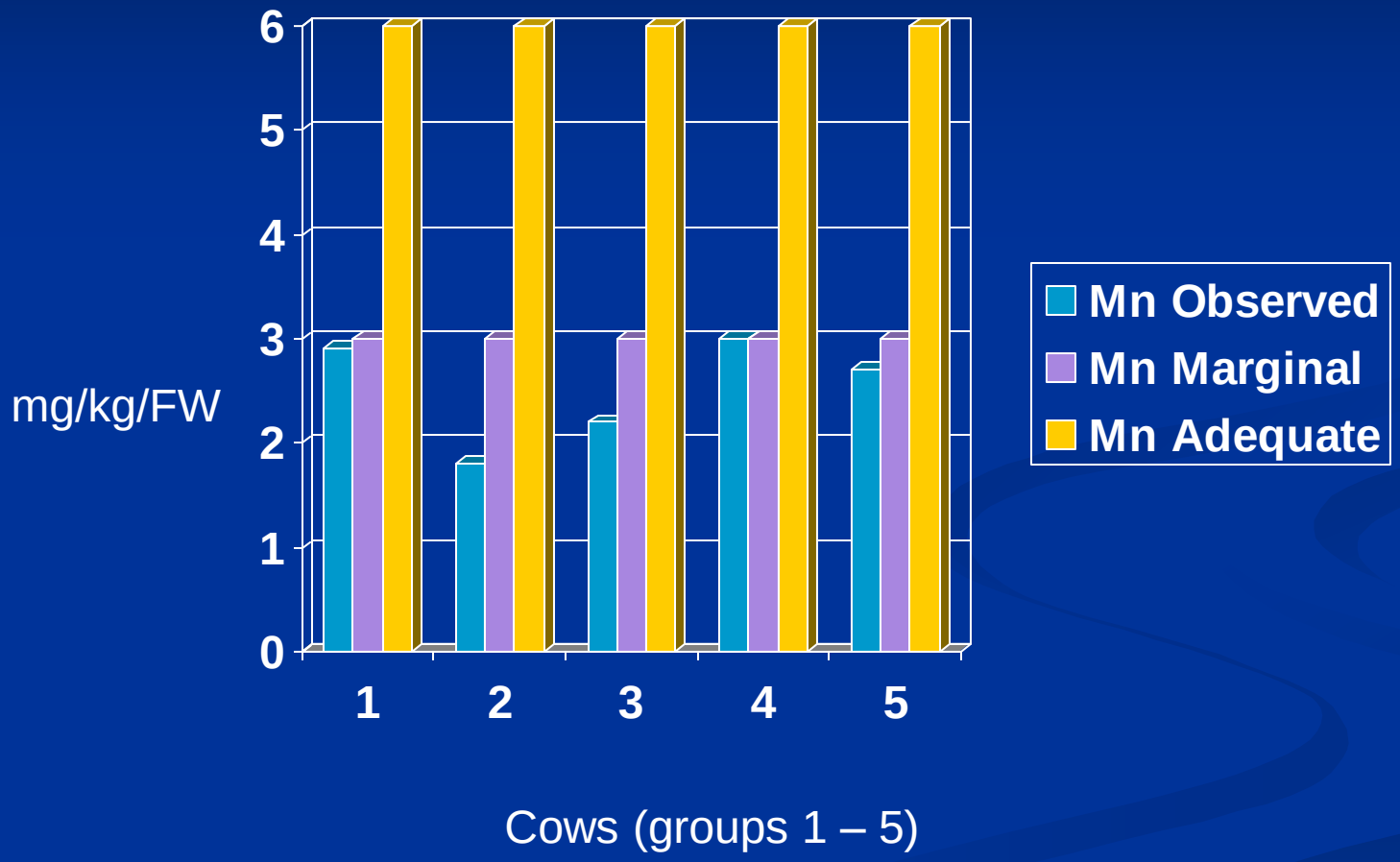
Examples:

Naturally occurring geochemical anomalies resulting in EDC effects.

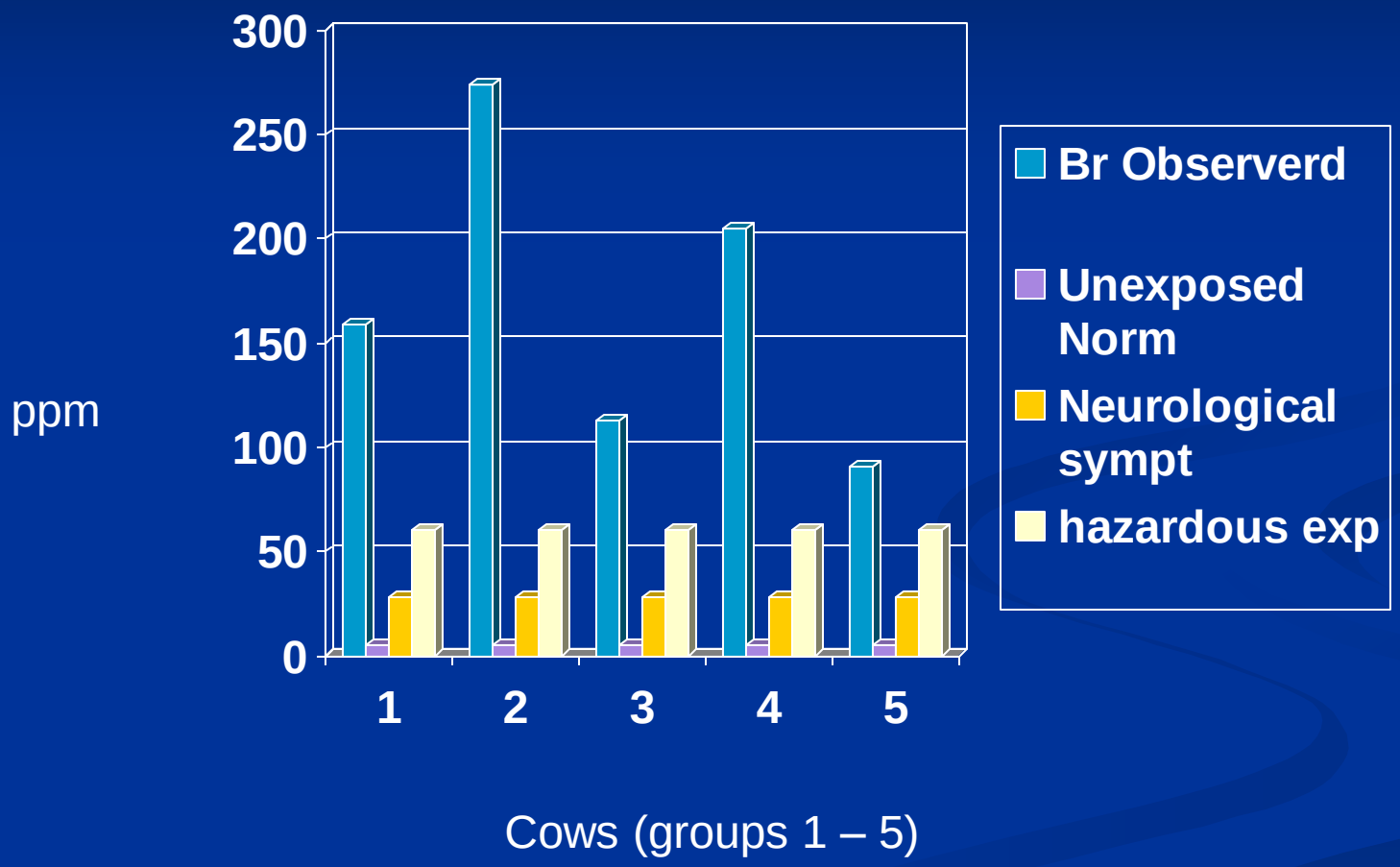
Examples:

Environmental impacts leading to a "cocktail" of exposures.

Liver results -Mn



Whole Blood results -Br

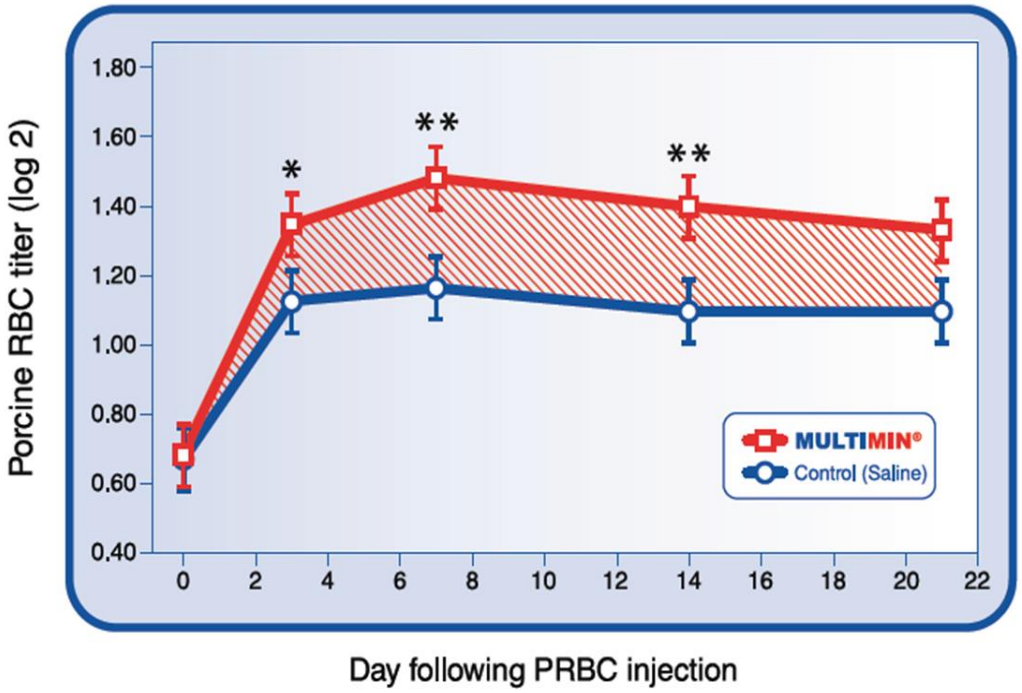


UNIVERSITY OF FLORIDA STUDY DATA

STUDY 2

STUDY RESULTS

- Average daily gain was greater (P=0.06) for **MULTIMIN®** treated heifers. (0.69 vs 0.57 lb/d)
- Heifers treated with **MULTIMIN®** had more PRBC neutralizing antibody titers on day 3, 7, and 14 following challenge compared to control heifers.
- Liver concentrations of Se were greater (P < 0.01) in **MULTIMIN®** versus control heifers.



Porcine red blood cell (PRBC) neutralizing antibody titers measured on d 0, 3, 7, 14, and 21 relative to PRBC injection. $P \leq$ * 0.10 and ** 0.05.

THE BOTTOM LINE

MULTIMIN may increase bodyweight gain, humoral immune response and trace mineral status of growing heifers.

RSA – WRC K5/1686/1

Downstream water samples collected 2007/8 = positive:

- Reporter gene assays:

Recombinant Yeast Oestrogen screen assay

- Competitive Oestrogen Receptor binding assay:

hER


5

Challenges

Example#1: Restriction#4 (WRC TT 262/06).

May not dispose of wastewater within 200 m of borehole or surface water.

This effectively implies no application of wastewater from feedlot effluent within the prescribed buffer zone.

Challenges

Example # 2:

Even if a GA or Licence has been obtained,

the new conditions for renewal and compliance may be contravened

and they can be revoked.

DWS: Monthly Monitoring

Is a legal compliance requirement (Sect 21):

Remains a producers best defense to argue for:

- continued use
- possible expansion
- action against other polluters
- lower monitoring frequency

DWS: Monthly Monitoring

AND!

Provides the information needed to

Assess fitness for use and thus manage water quality.

TOPICS - sampling

Laboratory Specifications (acidify ICP-MS!)

Point of Use considerations

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TDS	3000	Manganese	
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Aluminium	5.00	Molybdenum	0.50
Arsenic	0.50	Nickel	1.00
Beryllium	0.10	Selenium	0.05
Boron	5.00	Uranium	0.02
Cadium	0.02	Vanadium	0.10
Chromium	1.00	Zinc	50.00

INTERNATIONAL GUIDELINES:

Trace elements:

Co	Li	Se
Br	As	Zn
Sr	Ni	Mo
Mn	Cr	V
Ti	B	Be
Cu	Ba	Bi
Pb	Tl	Hg
Pt	Rb	La
U	Cs	I
Te	Sb	Sn
Cd	W	Fe

Assessment: Starting Point?

Diagnostic?

Legal compliance?

- Proactive management?

Water Quality Treatment PURPOSE?

Are you trying to be SAFE?
Who is the customer?

Drinking Water or Fluid & Electrolyte Maintenance?

$\neq$

The Way Forward

Confined Animal Feeding Operations – already attracting attention from Authorities.

The Way Forward

It is prudent to ensure that from a Legal Compliance Perspective addressing use and wastewater, that a good impression is created.

PROCESS Summary:

Assess Inherent Water Quality

Evaluate any Water Treatment Process

Look for meaningful ways to improve

Take note of the NWA Section 21 Activities relevant (ensure compliance with WUL / GA)

Observations

- "..due to the vague nature of the clinical signs of V toxicity and the lack of definitive tools for diagnosing this disease it is very difficult to conclusively prove that an animal is suffering from V toxicity.."

(Gummow, 2005)

Key Challenges

A change in mindset from
"health" and "safety"
to
"performance"
is needed.