The Fates of Endocrine Disruptors in Consumer Products: Bisphenol A

Prepared by Dr. Matthew A. DeNardo for the One Health One Planet Conference on March 8, 2018 at Phipps Conservatory

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A multidisciplinary investigation of the technical and environmental performances of TAML/peroxide elimination of Bisphenol A compounds from water.

Green Chemistry doi:10.1039/C7GC01415E

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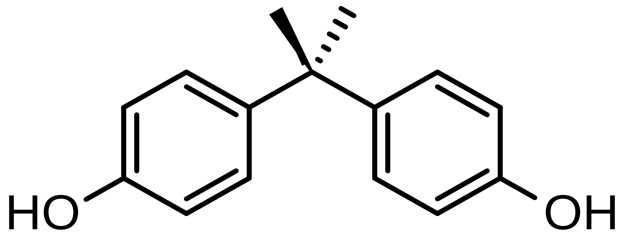
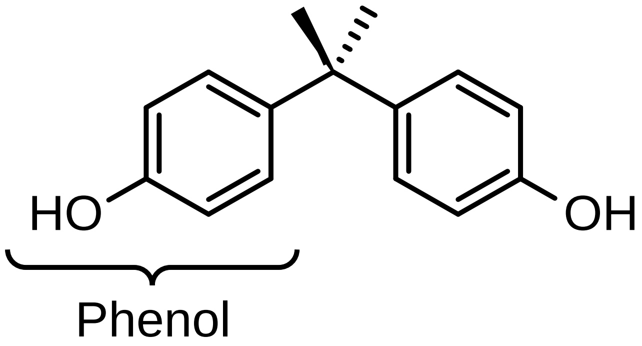
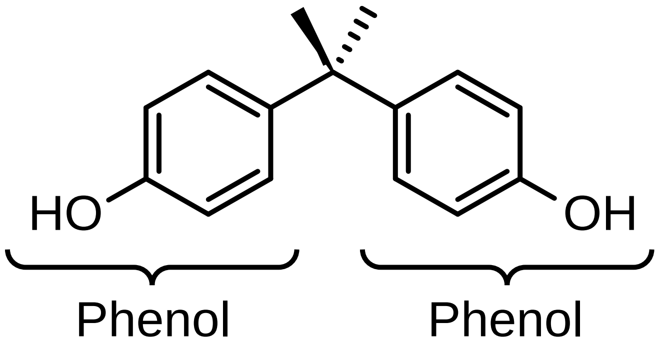


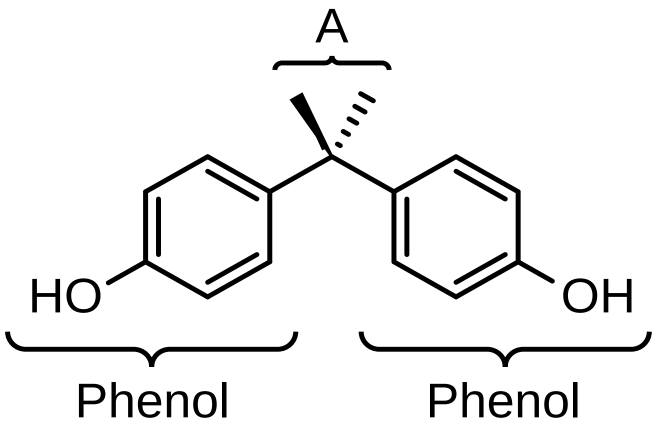
Bisphenol A



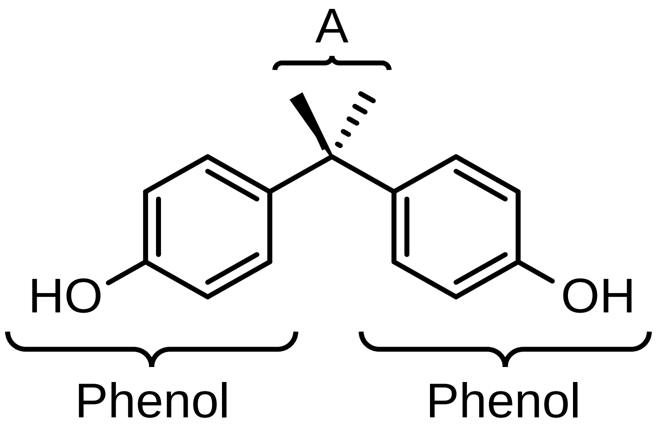
Bisphenol A



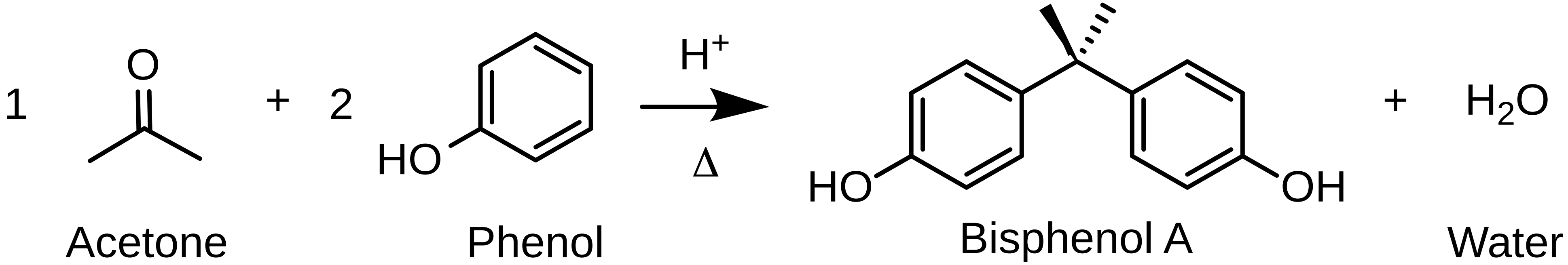
Bisphenol A

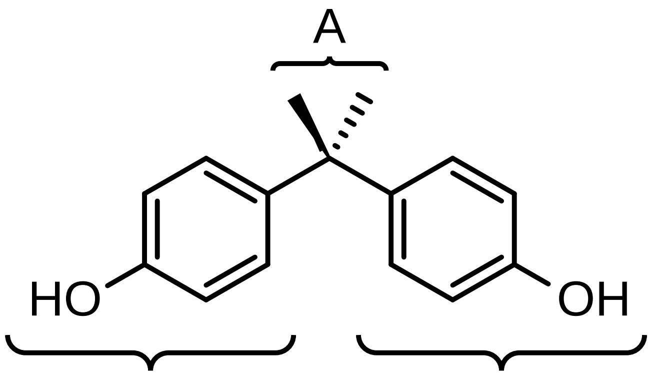


Bisphenol A

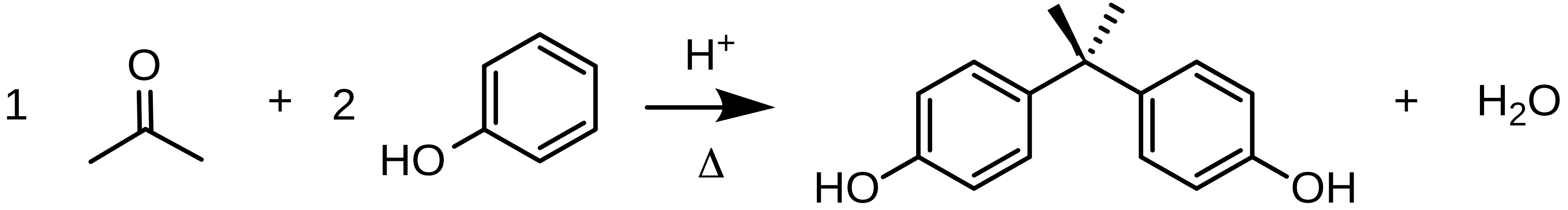

A
HO
OH
Phenol
Phenol

Bisphenol A

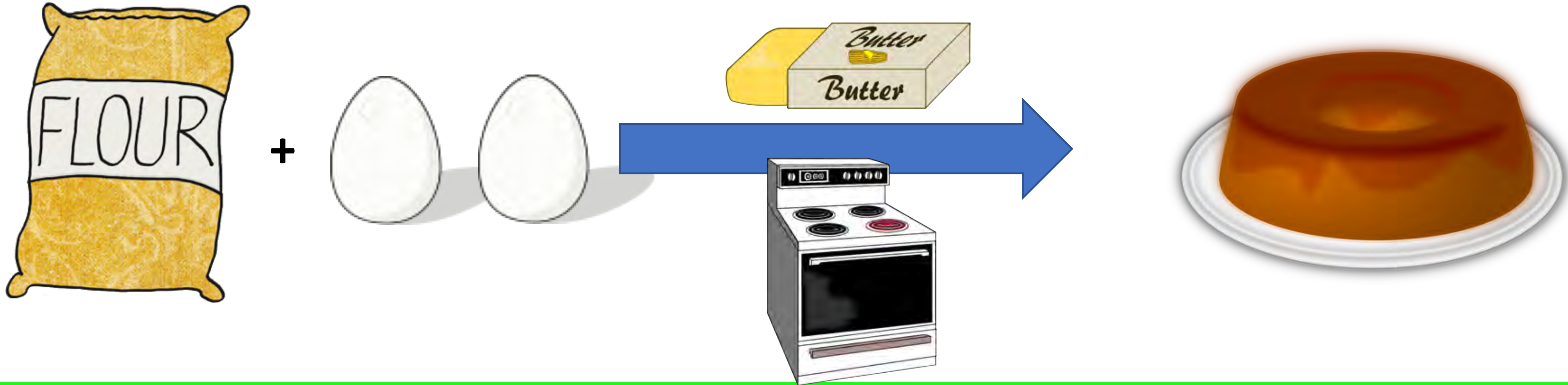

1
O
+
2
HO
H+
Δ
HO
OH
+
H2O
Acetone
Phenol
Bisphenol A
Water

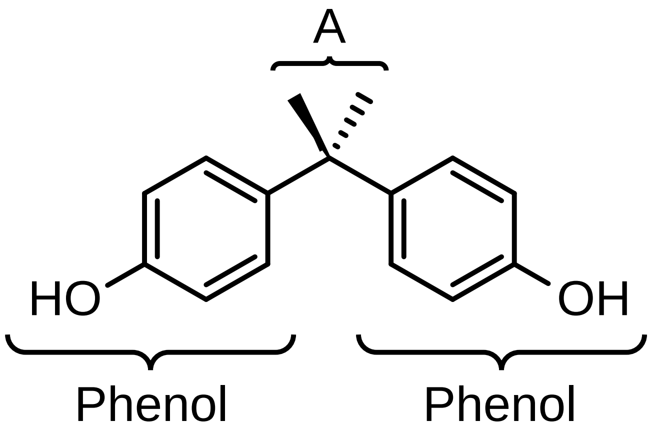


Bisphenol A

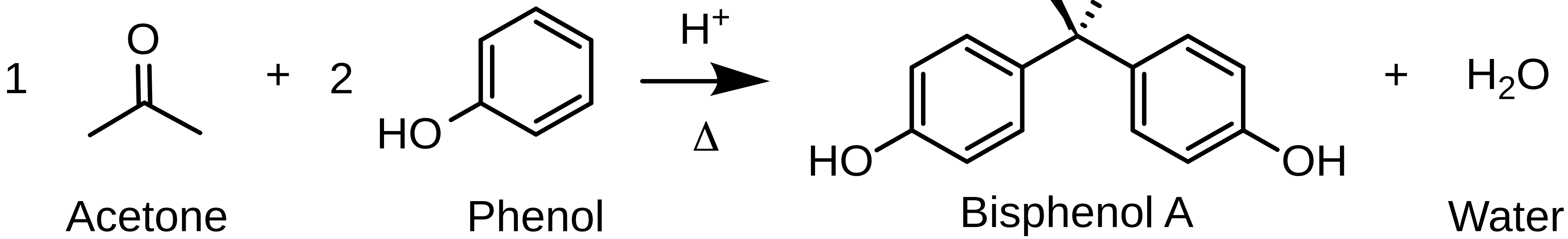


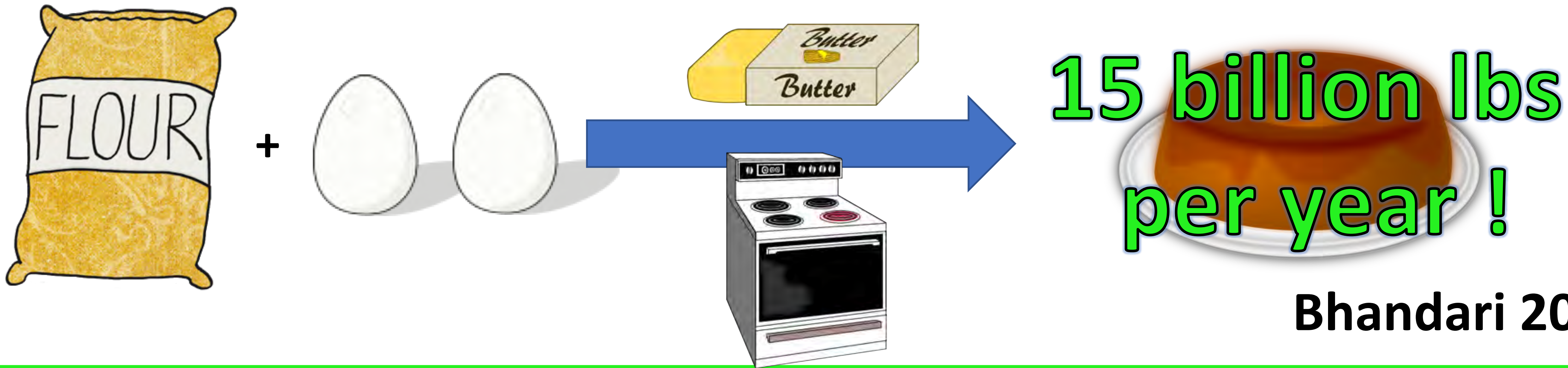
Acetone Phenol Bisphenol A Water



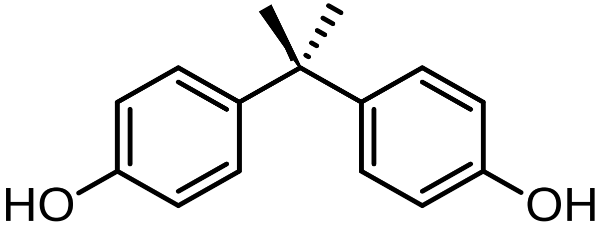


Bisphenol A

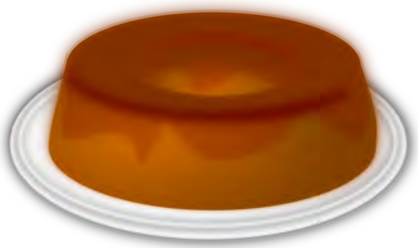


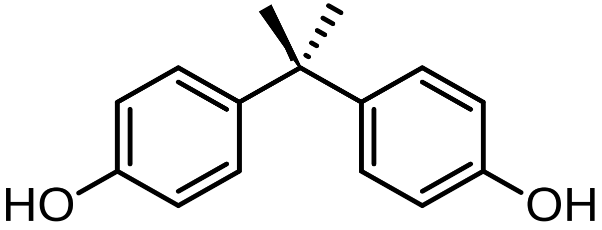


Bhandari 2015



Bisphenol A





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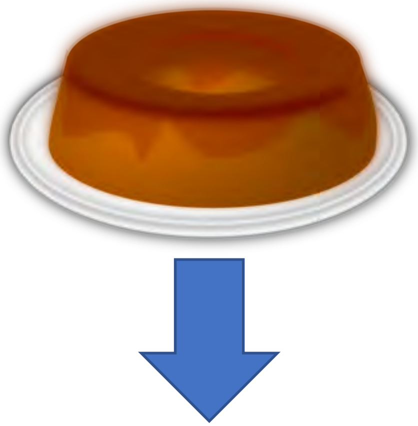

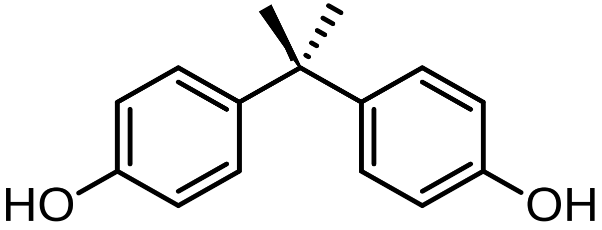

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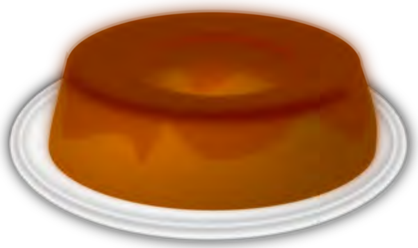
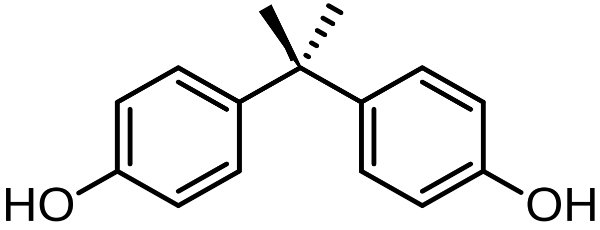



SHOP
Article Count Amount Tax
T-Shirt XL......1 $14,95 20%
Jeans PDK.......2 $39,90 20%
GROSS $75,80
TAX $18,95
SUM $94,75



Bisphenol A


SHOP
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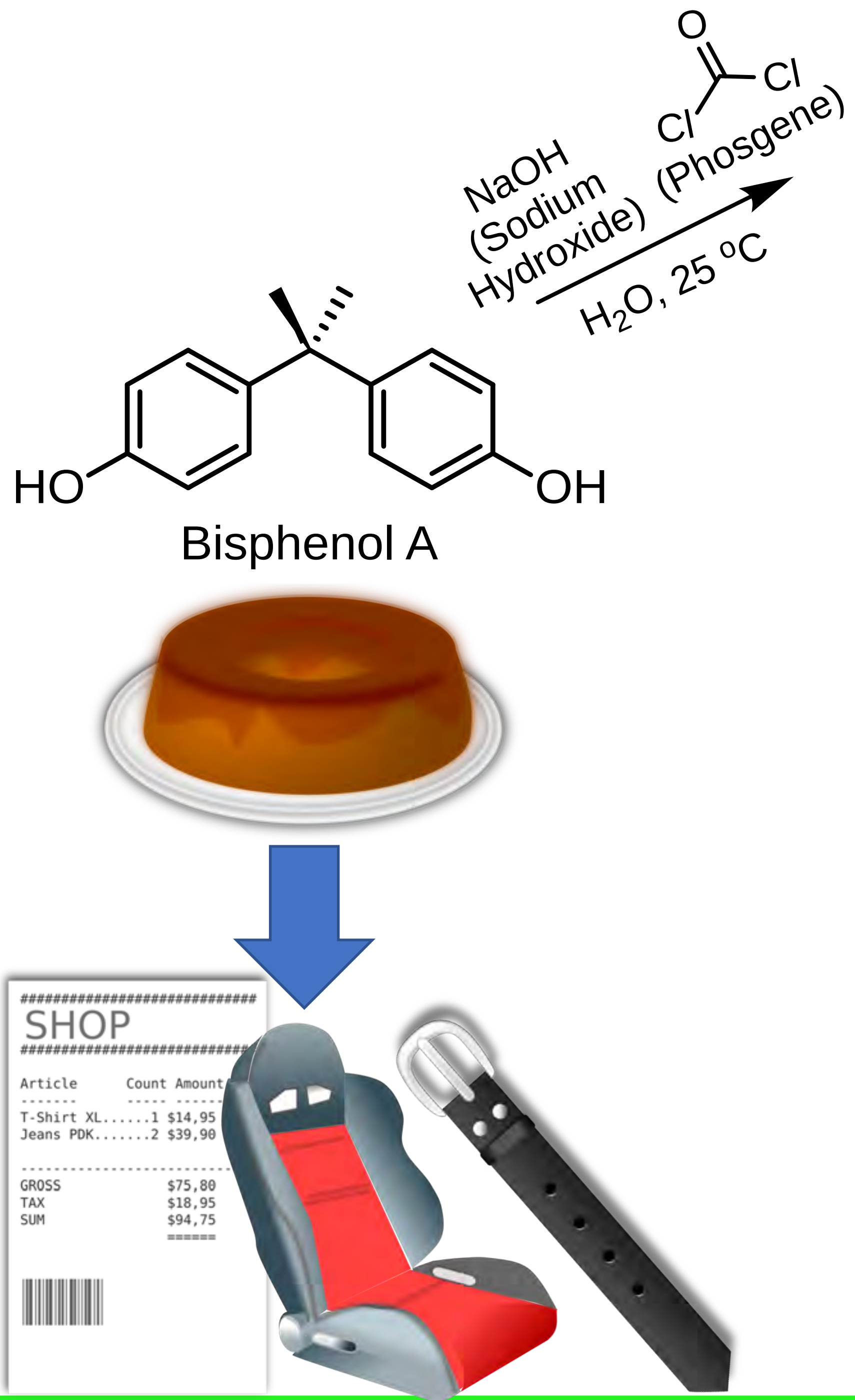

NaOH (Sodium Hydroxide)
(Phosgene)
H_2O, 25 °C
Bisphenol A
SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
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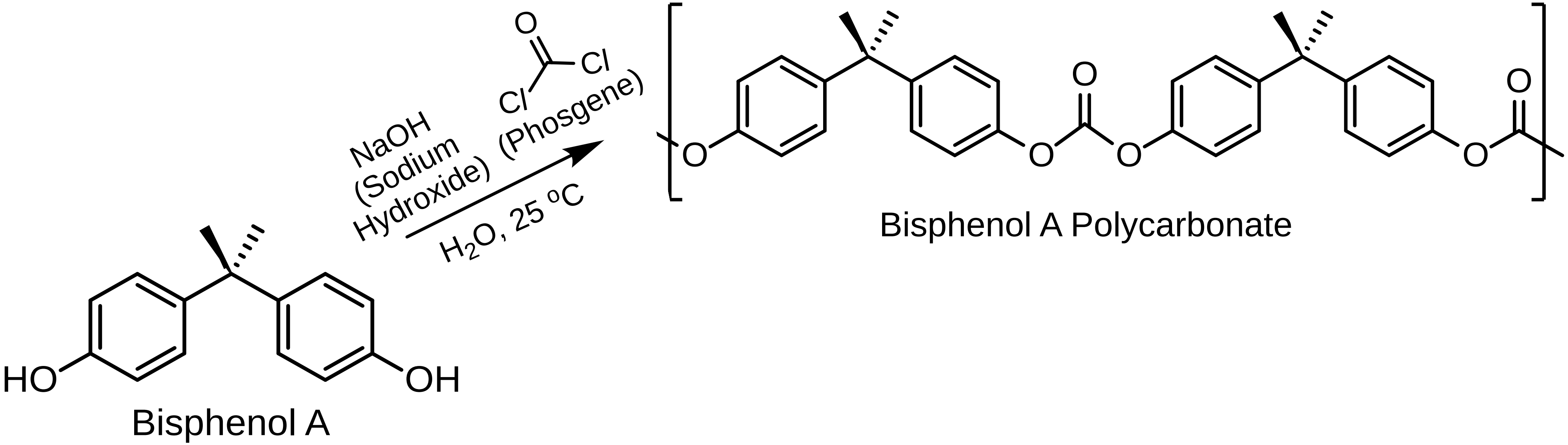
NaOH
(Sodium
Hydroxide)
(Phosgene)
H_2O, 25 °C
HO
OH
Bisphenol A
Bisphenol A Polycarbonate


SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
GROSS $75,80
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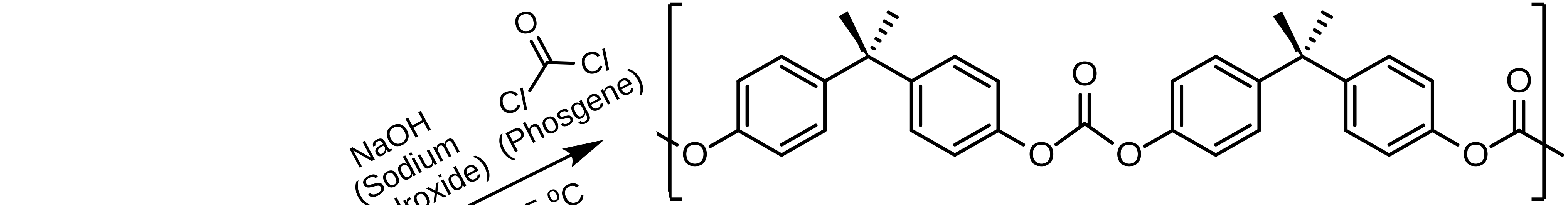
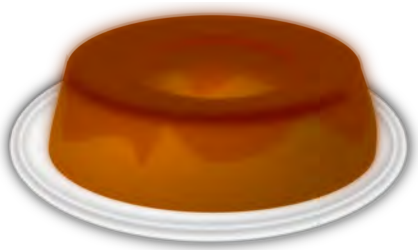
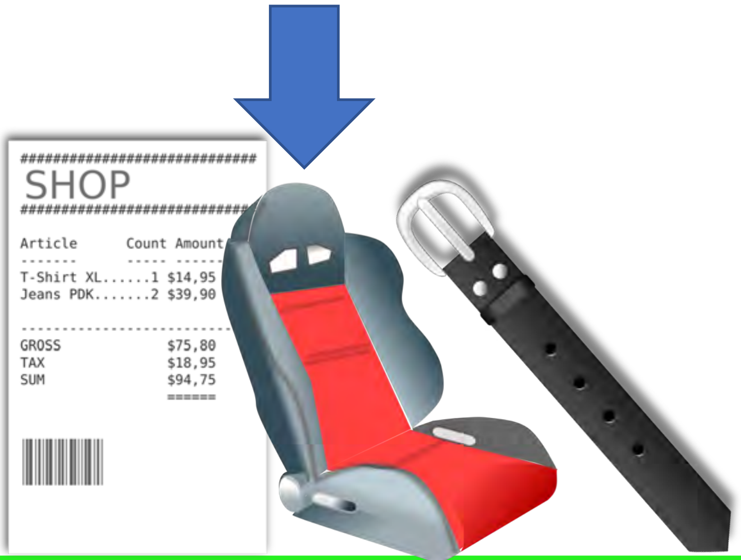
SUM $94,75

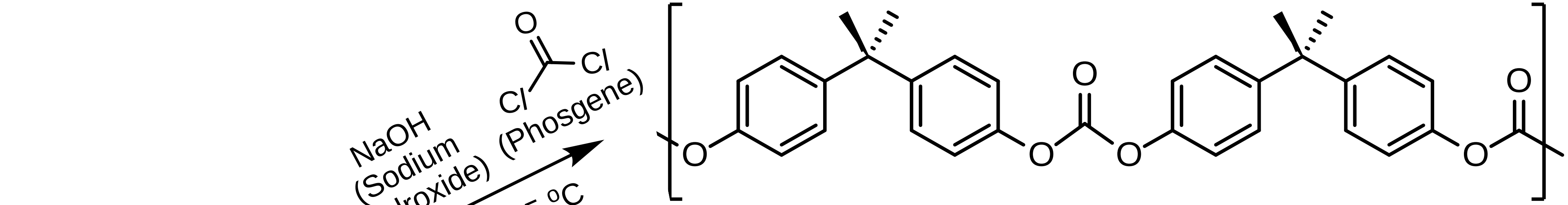


Bisphenol A

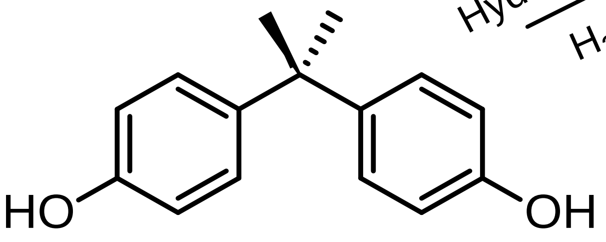
Bisphenol A Polycarbonate







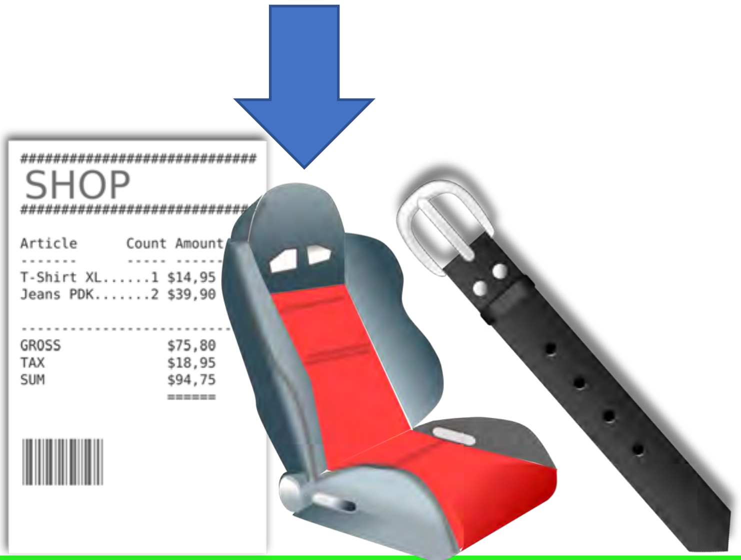
Bisphenol A Polycarbonate

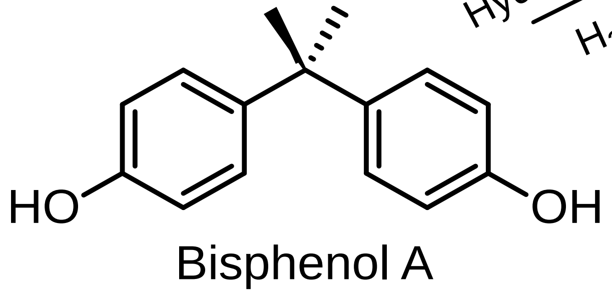


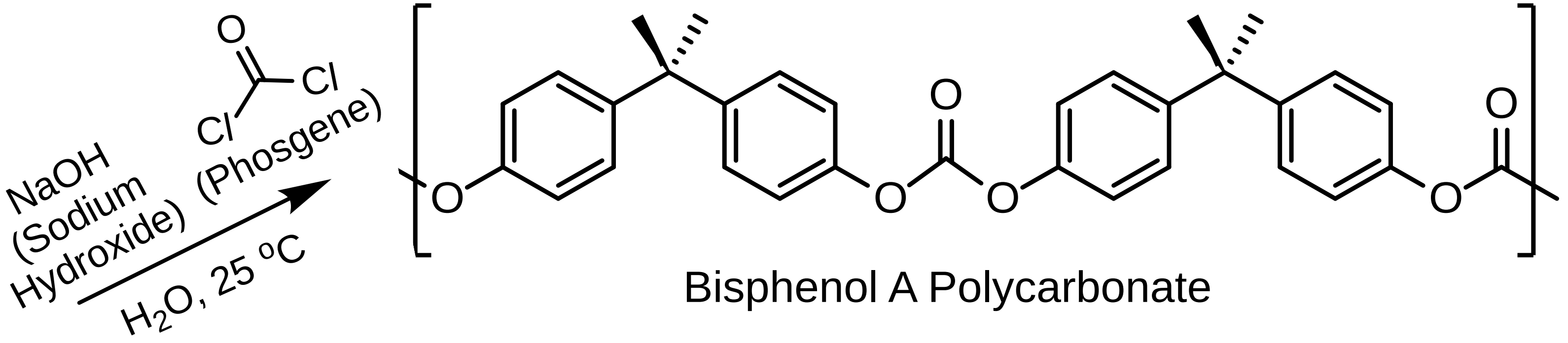
Bisphenol A

~60% of the produced BPA

Conseil 2015

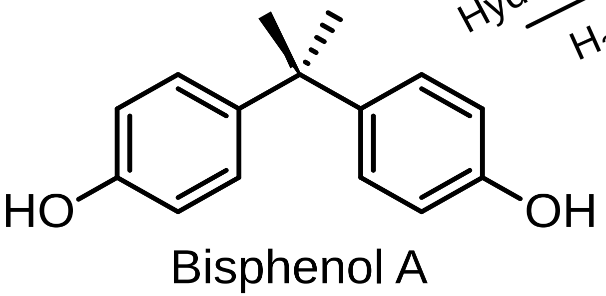
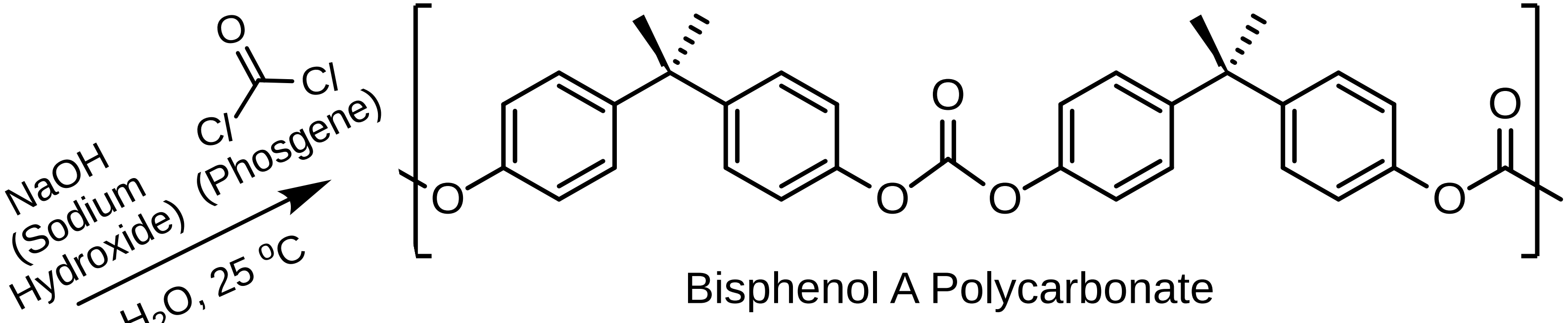


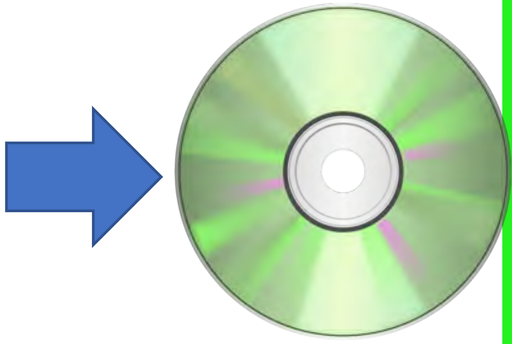




~60% of the produced BPA

Conseil 2015

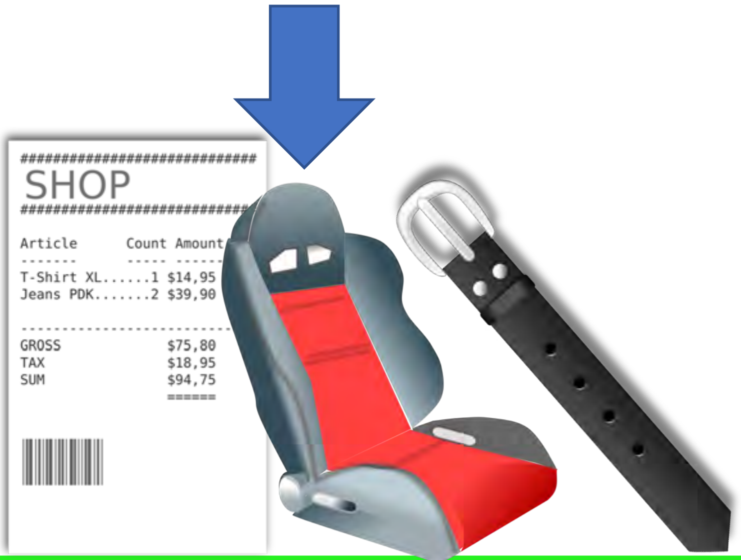



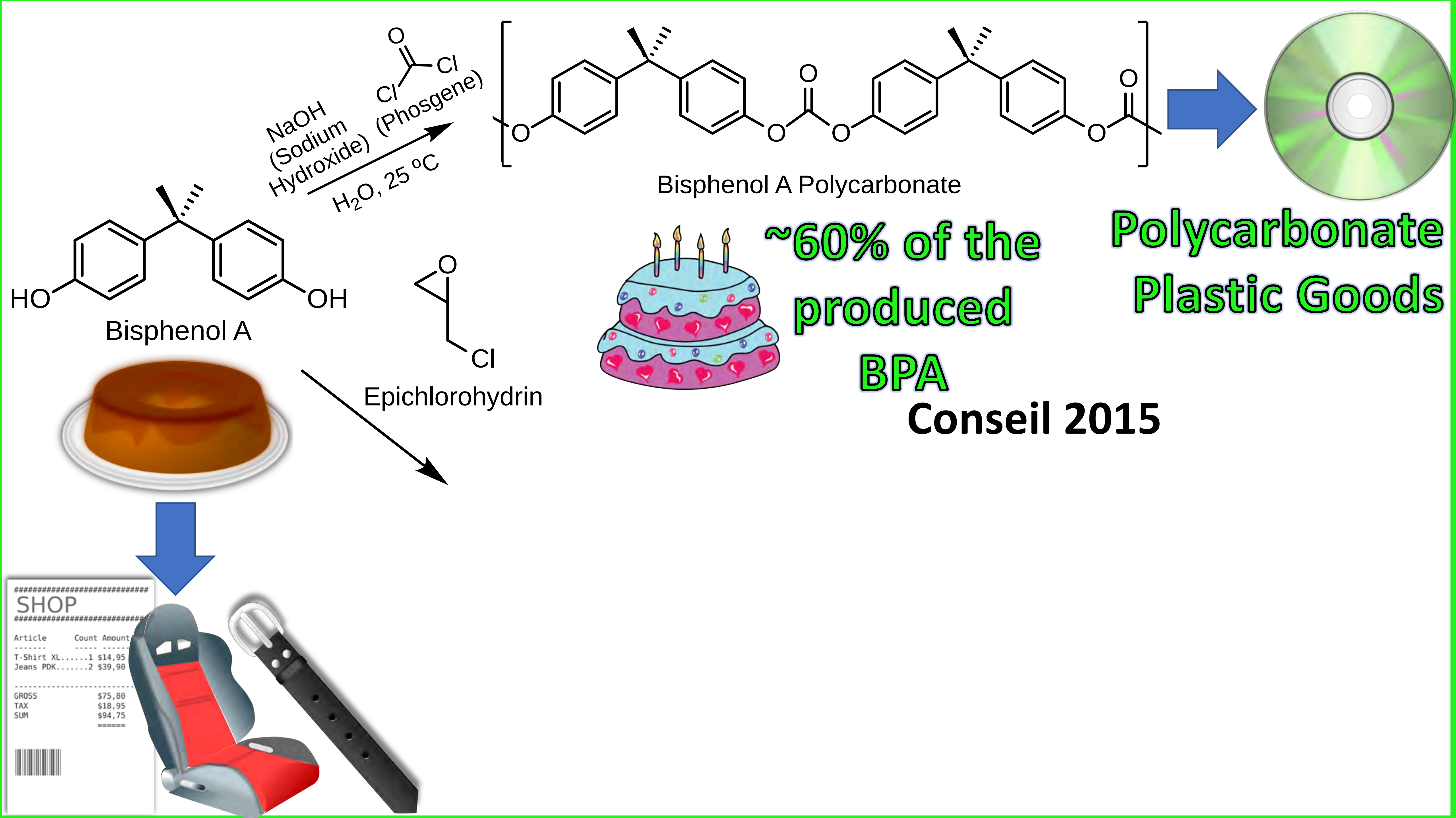


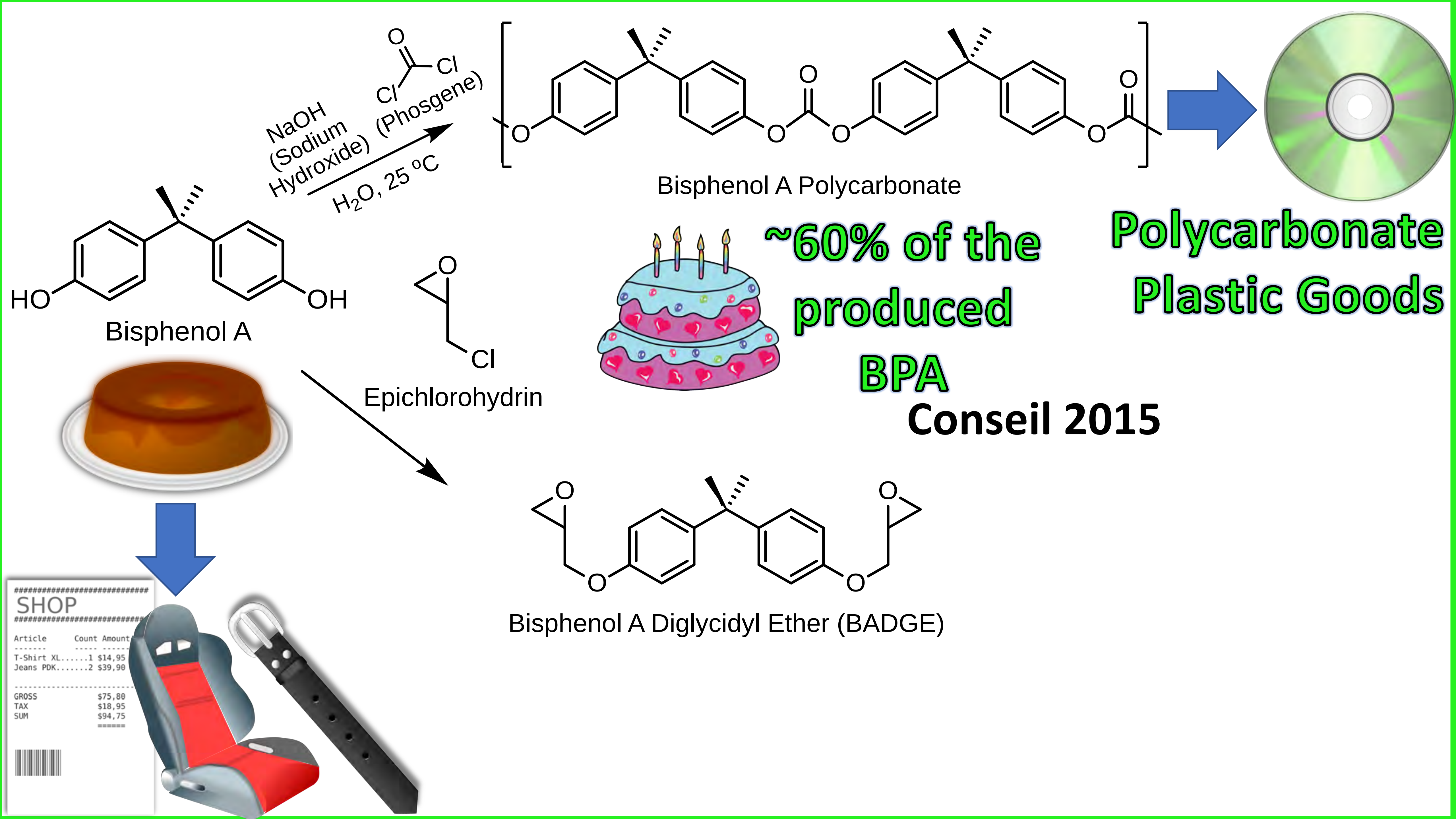
Polycarbonate Plastic Goods

~60% of the produced BPA

Conseil 2015




NaOH
(Sodium
Hydroxide)
(Phosgene)
H2O, 25 oC
Bisphenol A Polycarbonate
Bisphenol A
HO
OH
Epichlorohydrin
~60% of the
produced
BPA
Conseil 2015
Polycarbonate
Plastic Goods
SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
GROSS $75,80
TAX $18,95
SUM $94,75


NaOH (Sodium Hydroxide)
Cl O Cl (Phosgene)
H_2O, 25 °C
Bisphenol A Polycarbonate
HO OH
Bisphenol A
Epichlorohydrin
Bisphenol A Diglycidyl Ether (BADGE)
~60% of the produced BPA
Polycarbonate Plastic Goods
Conseil 2015
SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
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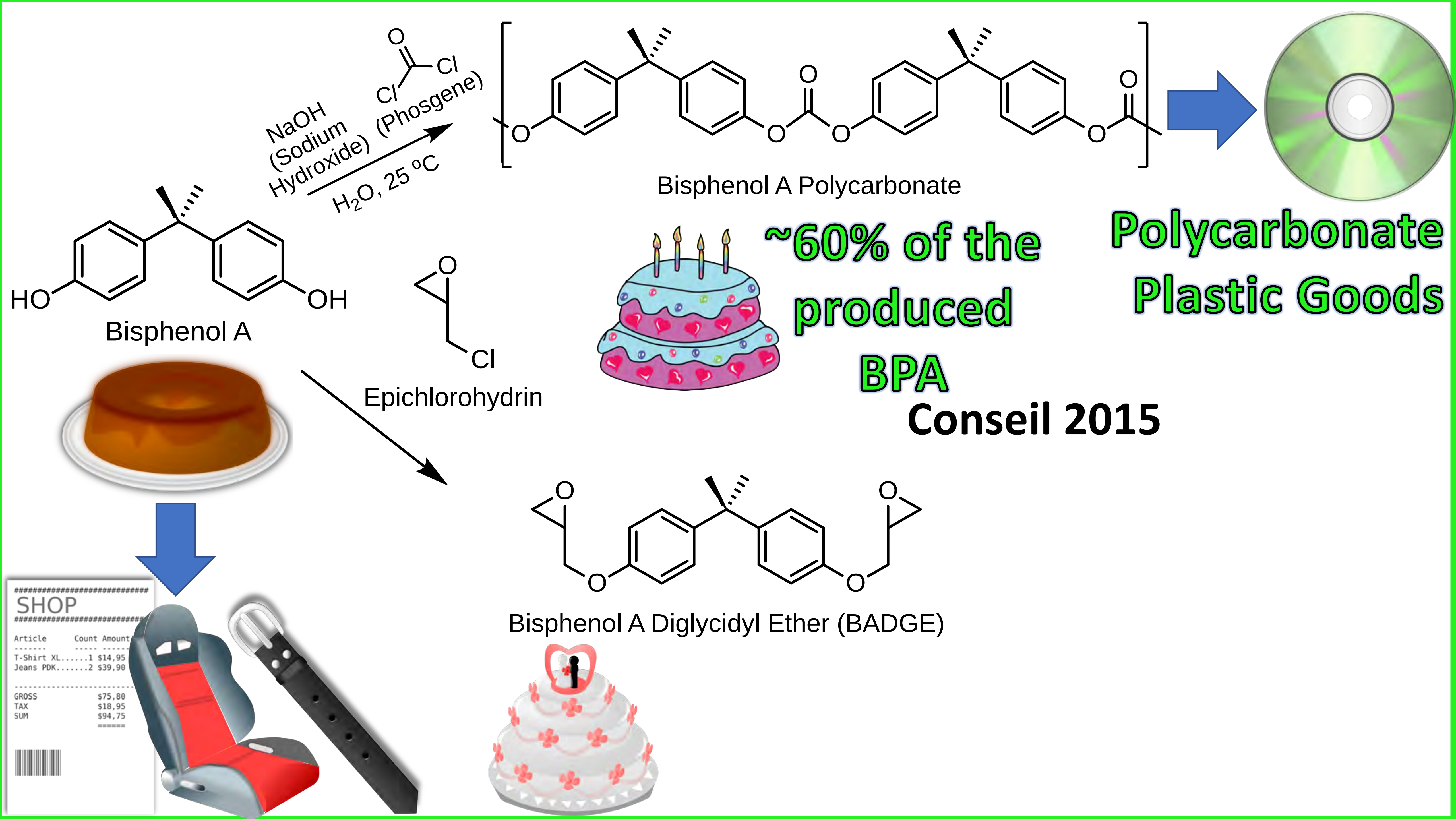

NaOH (Sodium Hydroxide)
(Phosgene)
H2O, 25 oC
Bisphenol A Polycarbonate
Polycarbonate Plastic Goods
~60% of the produced BPA
Conseil 2015
HO
OH
Bisphenol A
Cl
Epichlorohydrin
Bisphenol A Diglycidyl Ether (BADGE)
SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
GROSS $75,80
TAX $18,95
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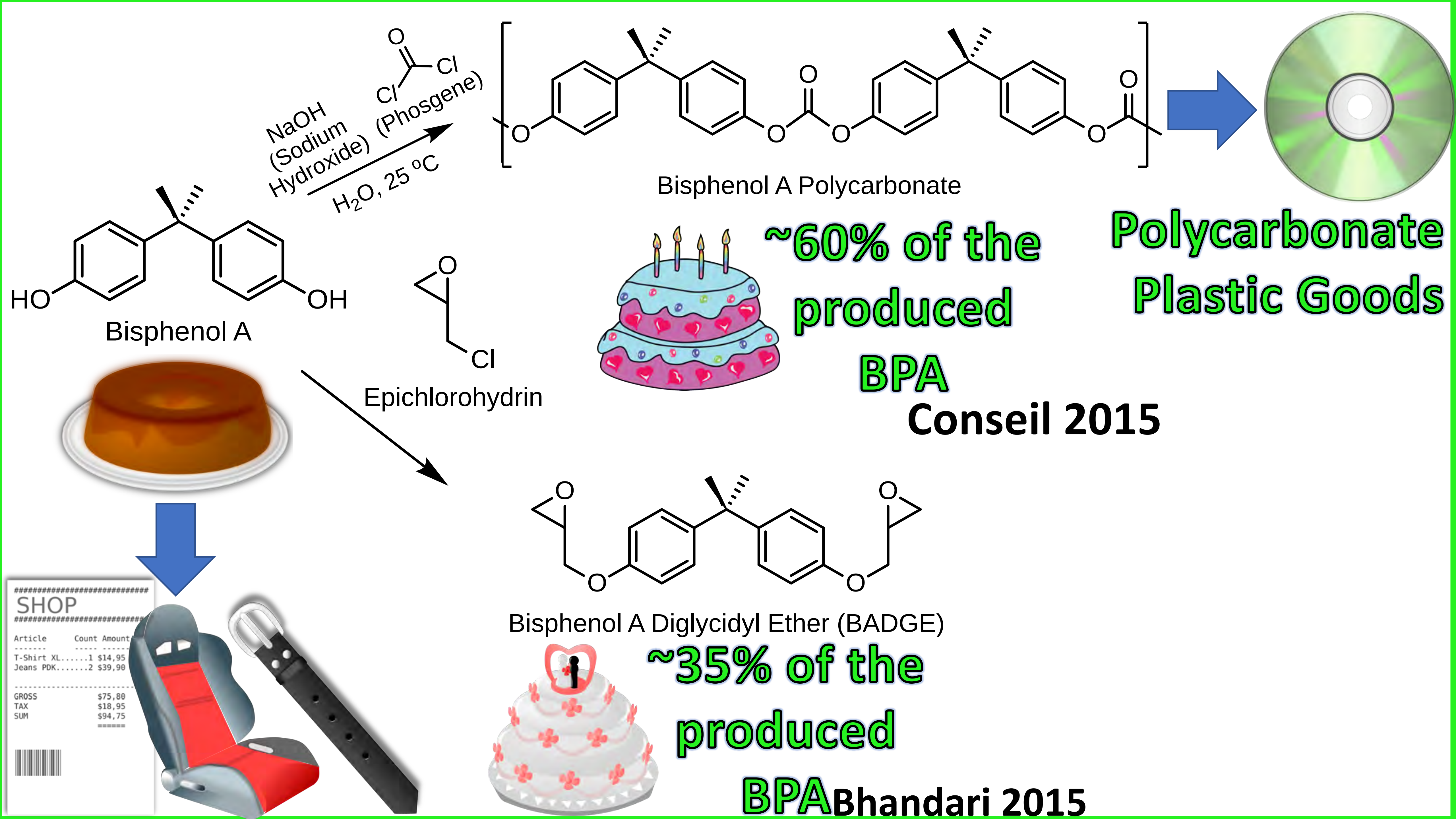
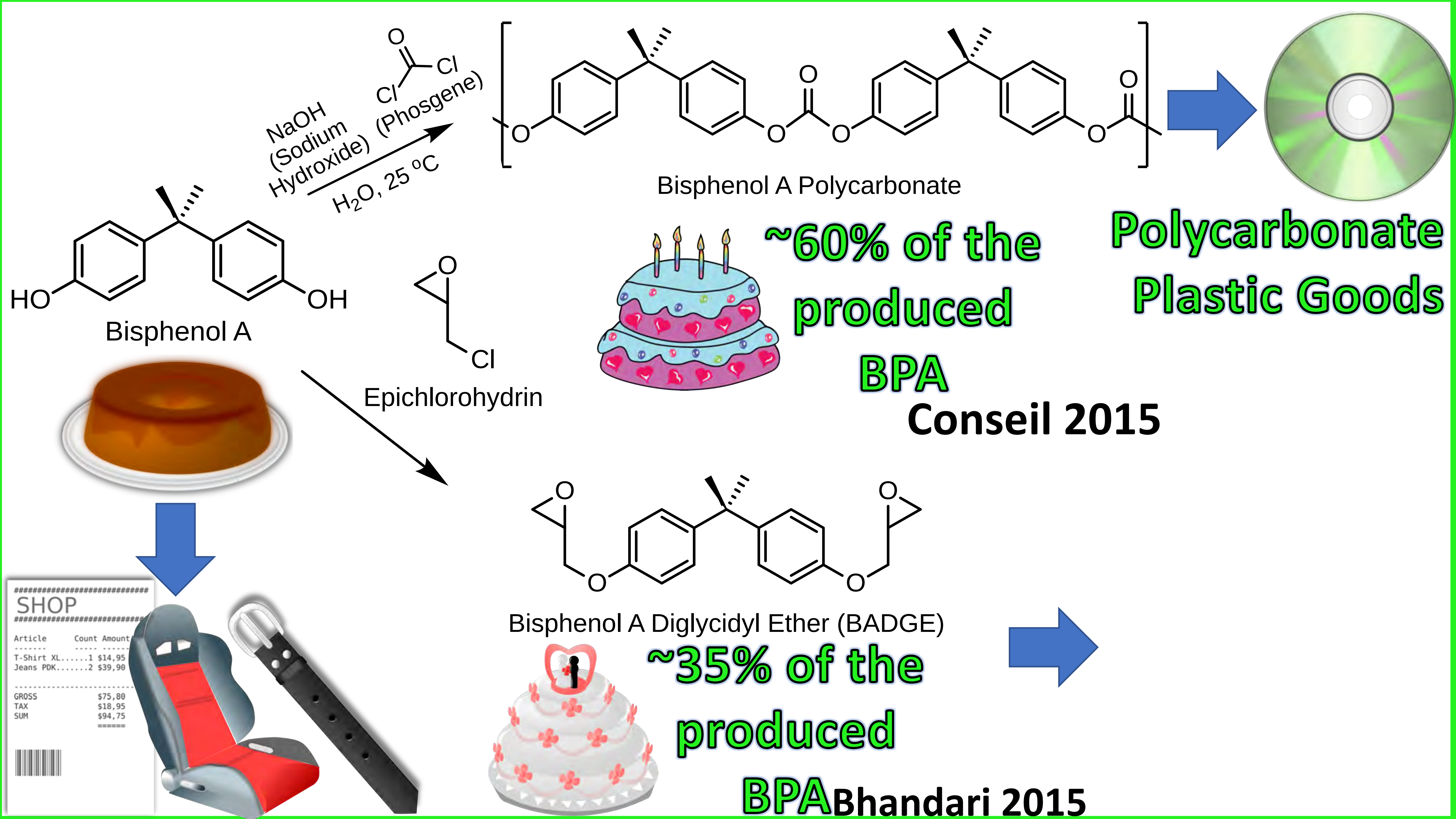


NaOH (Sodium Hydroxide)
(Phosgene)
H2O, 25 oC
Bisphenol A Polycarbonate
Polycarbonate Plastic Goods
~60% of the produced BPA
Conseil 2015
Bisphenol A
Epichlorohydrin
Bisphenol A Diglycidyl Ether (BADGE)
~35% of the produced BPA
Bhandari 2015
SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
GROSS $75,80
TAX $18,95
SUM $94,75



NaOH
(Sodium
Hydroxide)
(Phosgene)
H2O, 25 °C
Bisphenol A Polycarbonate
Polycarbonate
Plastic Goods
~60% of the
produced
BPA
Conseil 2015
HO
OH
Bisphenol A
Epichlorohydrin
Bisphenol A Diglycidyl Ether (BADGE)
~35% of the
produced
BPA
Bhandari 2015
SHOP
Article Count Amount
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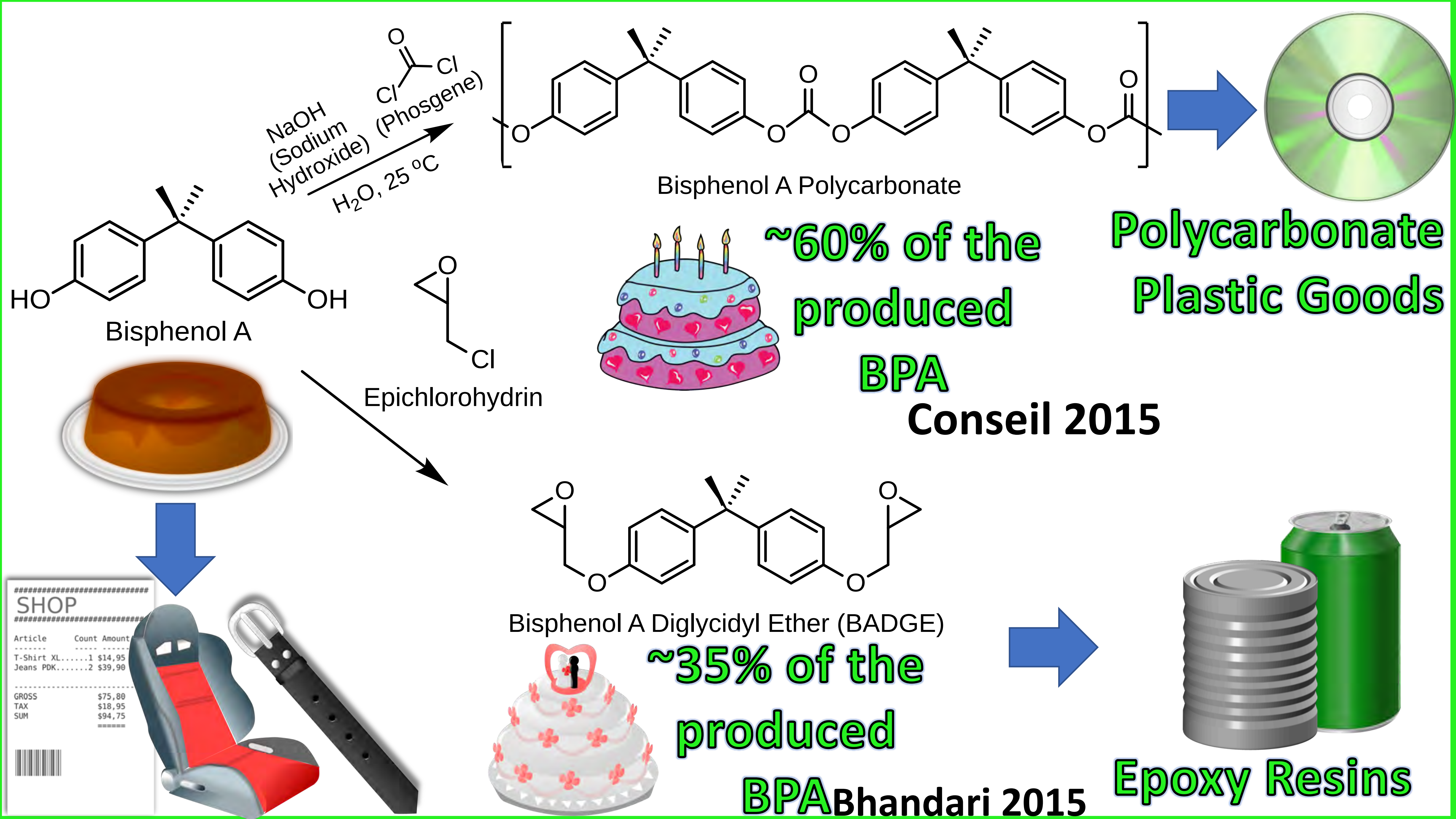
NaOH
(Sodium
Hydroxide)
(Phosgene)
H_2O, 25 °C
Bisphenol A Polycarbonate
Bisphenol A
Epichlorohydrin
~60% of the produced BPA
Conseil 2015
Polycarbonate Plastic Goods
Bisphenol A Diglycidyl Ether (BADGE)
~35% of the produced BPA
Bhandari 2015
Epoxy Resins
SHOP
Article
Count Amount
T-Shirt XL......1 $14,95
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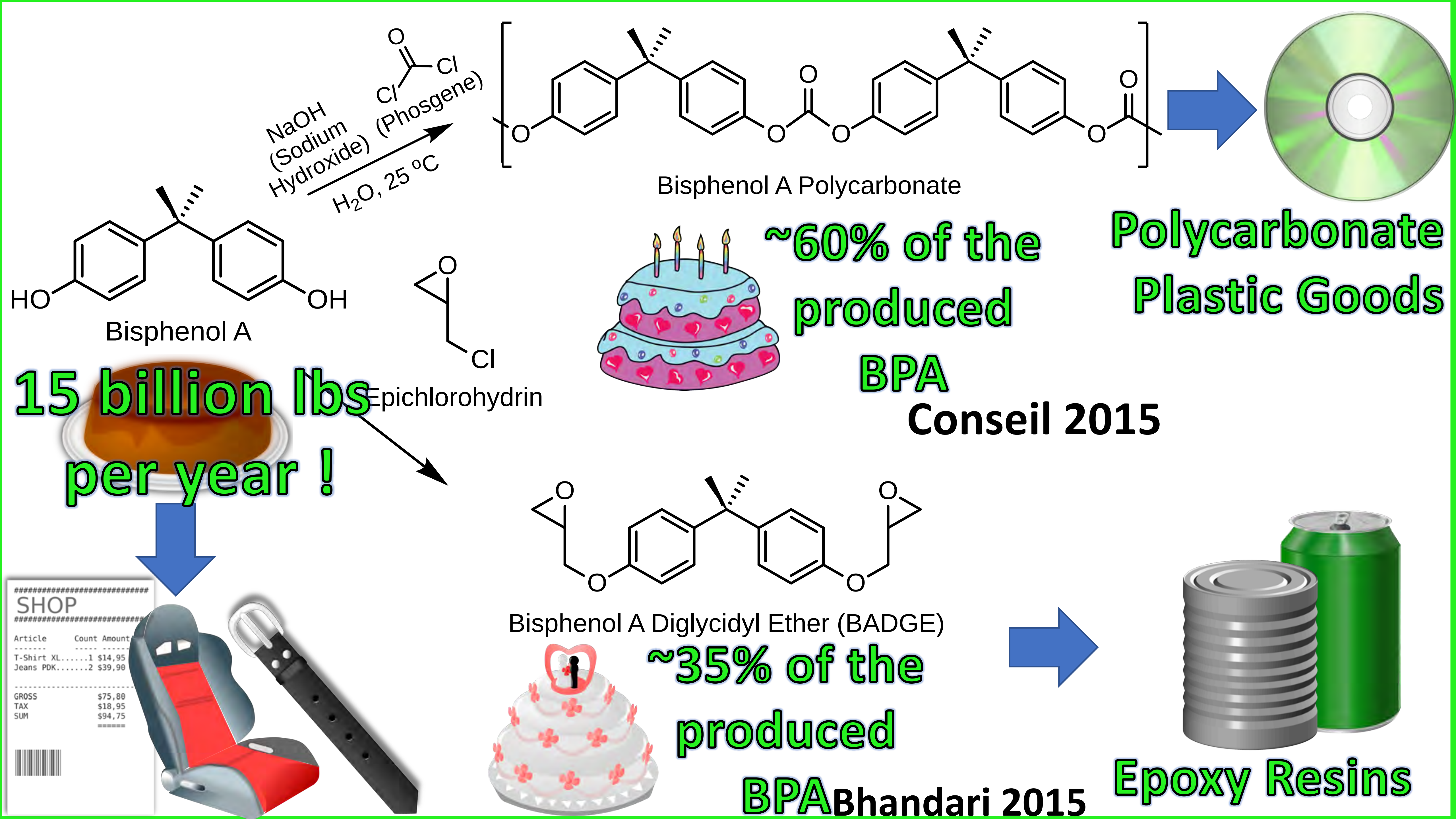
GROSS $75,80
TAX $18,95
SUM $94,75



NaOH (Sodium Hydroxide)
Cl Cl O (Phosgene)
H_2O, 25 °C
Bisphenol A Polycarbonate
Polycarbonate Plastic Goods
~60% of the produced BPA
Conseil 2015
HO OH
Bisphenol A
Cl
Epichlorohydrin
15 billion lbs per year !
SHOP
Article Count Amount
T-Shirt XL......1 $14,95
Jeans PDK.......2 $39,90
GROSS $75,80
TAX $18,95
SUM $94,75
Bisphenol A Diglycidyl Ether (BADGE)
~35% of the produced BPA
Bhandari 2015
Epoxy Resins

What Are the Consequences of The Mass Production of BPA?

Production

Production

Production

Production

Production

Production

Production

Production

Production

- *Contamination of Air*

Production

- *Contamination of Air*
- *Contamination of Water*

What Are the Concentrations of BPA in Industrial Effluents?

BPA Detected in Industrial Effluents

Effluent	Country	Year	Range ($\mu g\ L^{-1}$)	Mean ($\mu g\ L^{-1}$)	Ref.
Chemical Industry	Austria	2000	2.5–50	18	Furhacker 2000
Paper Production and Recycling	Austria	2000	28–72	41	Furhacker 2000
Paper Production and Recycling	Japan	2002	0.2–370	59	Fukazawa 2002
Plastics Manufacturing and Recycling	Nigeria	2015	108–163	130	Mackinwa 2015

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Luo 2014

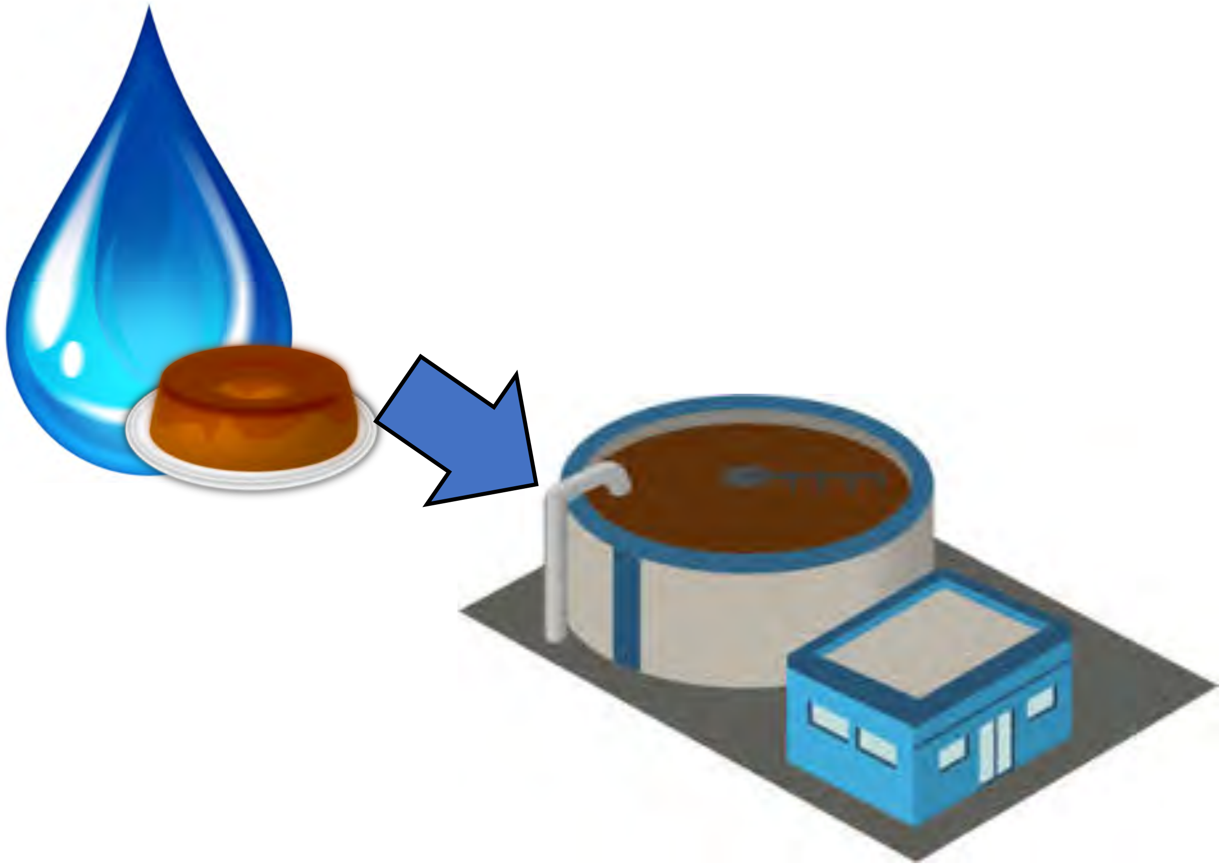
Lee 2004

NeBRA 2007

Luo 2014

Lee 2004

NeBRA 2007



Luo 2014
Lee 2004
NeBRA 2007

What Are the Concentrations of BPA in Municipal Influents?

Concentrations of BPA Detected in Municipal Wastewater Treatment Plant Influents

Country	Year	Range ($\mu g\ L^{-1}$)	Mean ($\mu g\ L^{-1}$)	Ref.
Austria	2000	10–37	21	Furhacker 2000
Canada	2004	0.16–28.1	—	Lee 2004
Germany	2008	<0.02–12.2	3.67	Hohne 2008

Concentrations of BPA Detected in Municipal Wastewater Treatment Plant Influents

Country	Year	Range ($\mu g\ L^{-1}$)	Mean ($\mu g\ L^{-1}$)	Ref.
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Concentrations of BPA Detected in Municipal Wastewater Treatment Plant Influents

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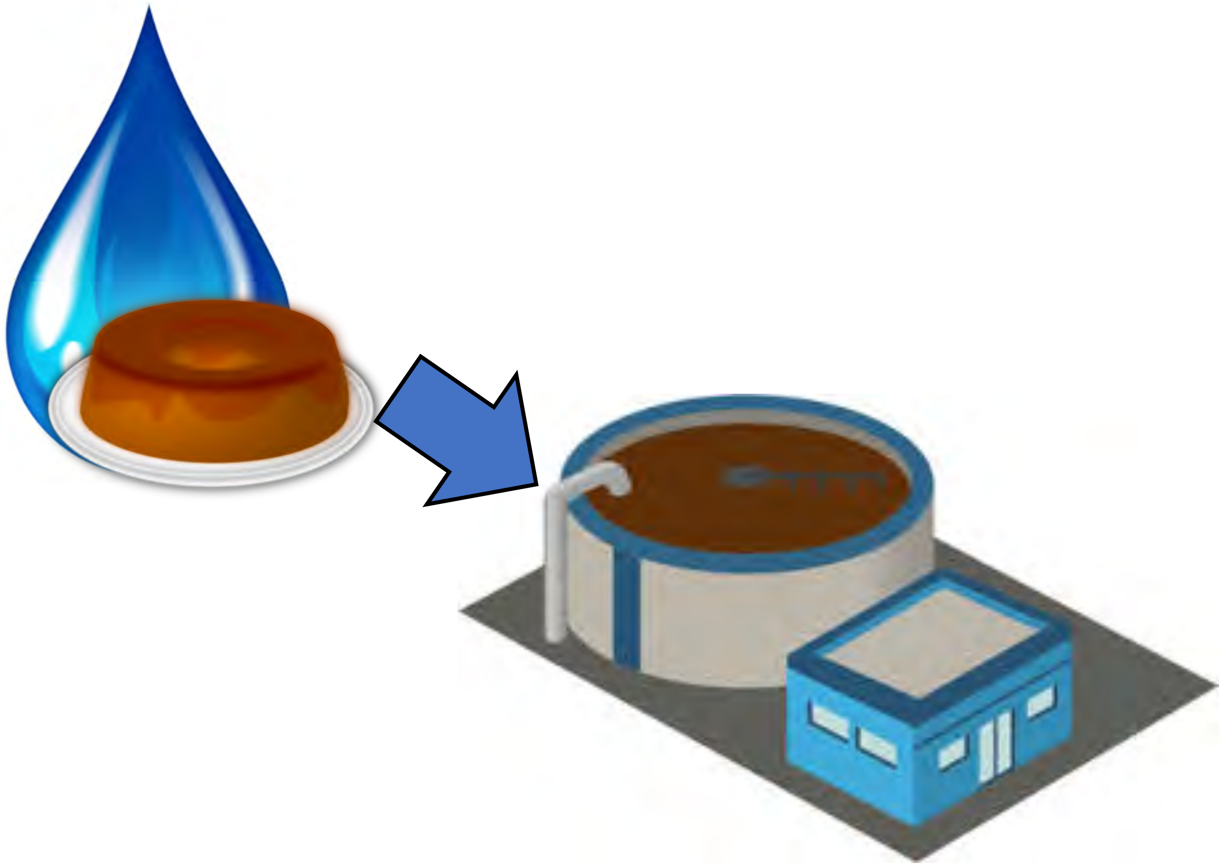
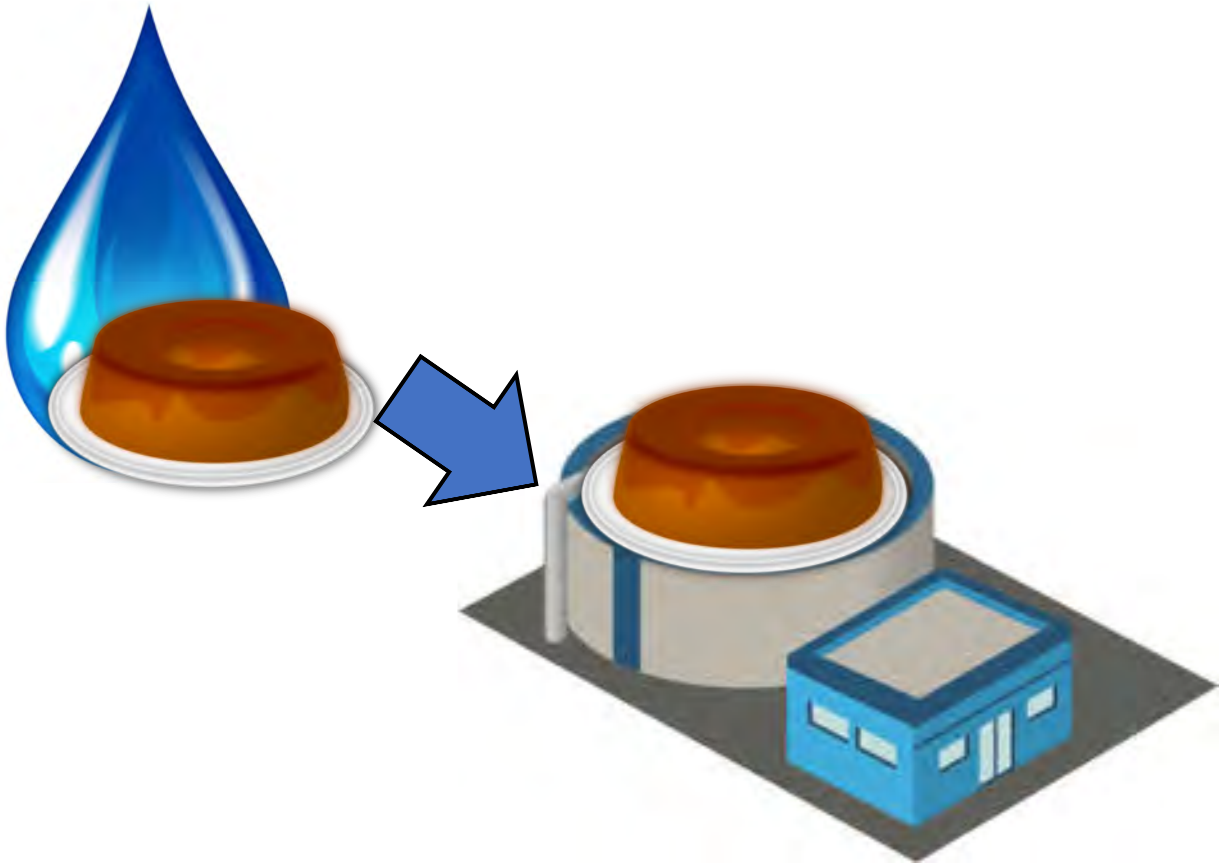
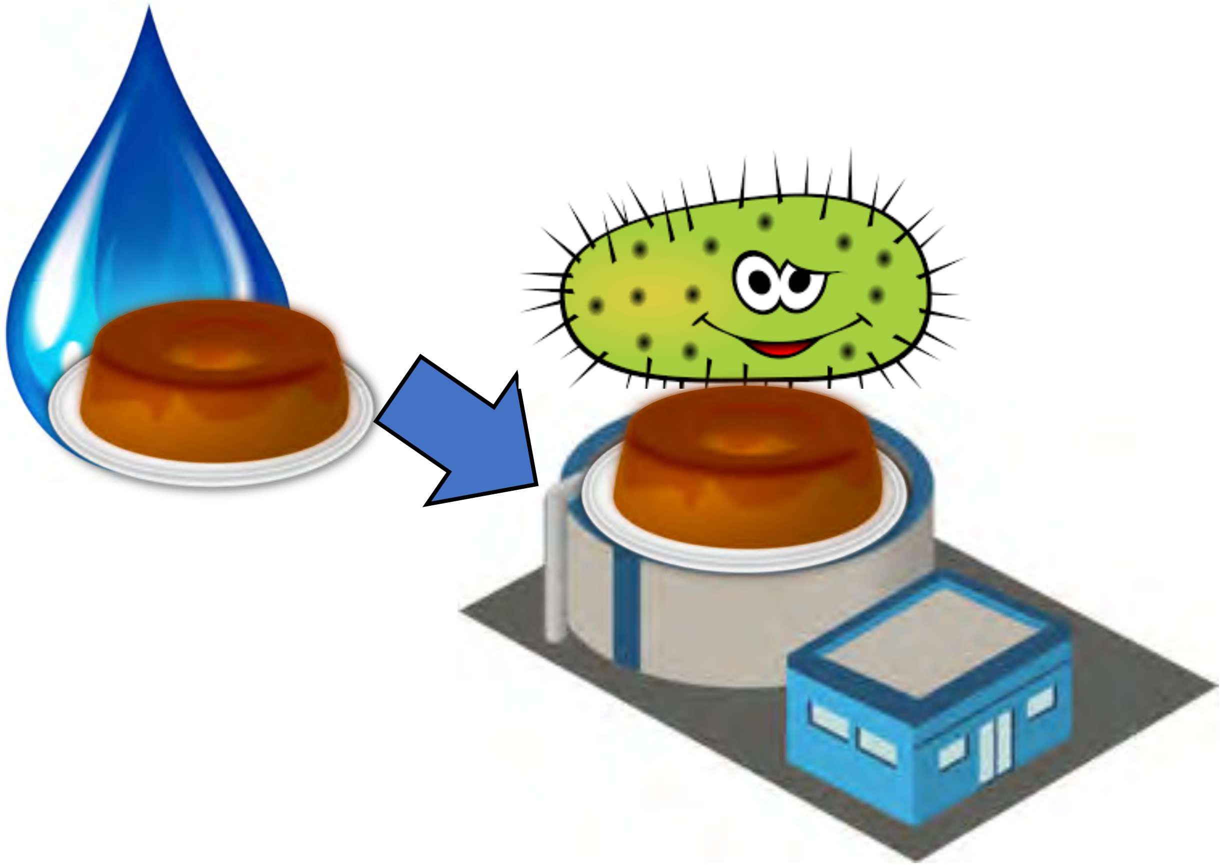


Luo 2014
Lee 2004
NeBRA 2007



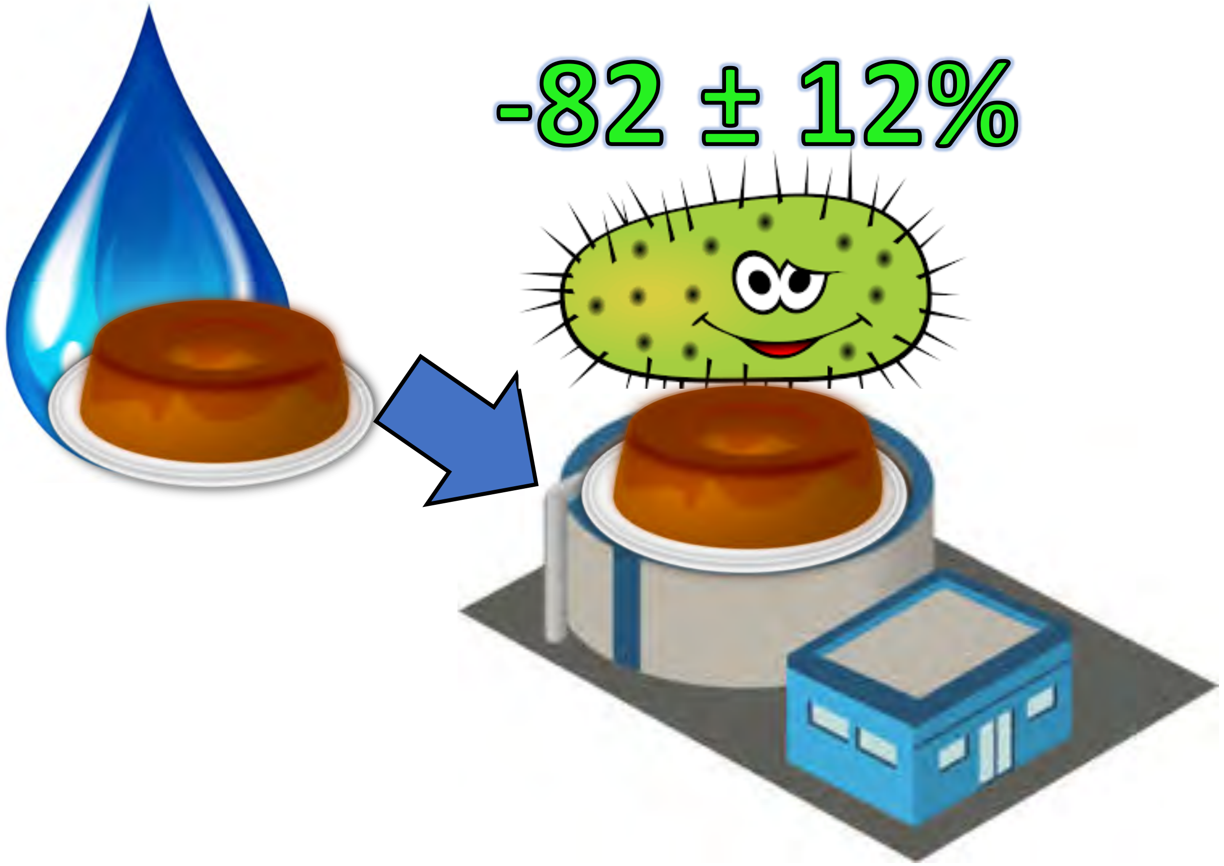
Luo 2014
Lee 2004
NeBRA 2007



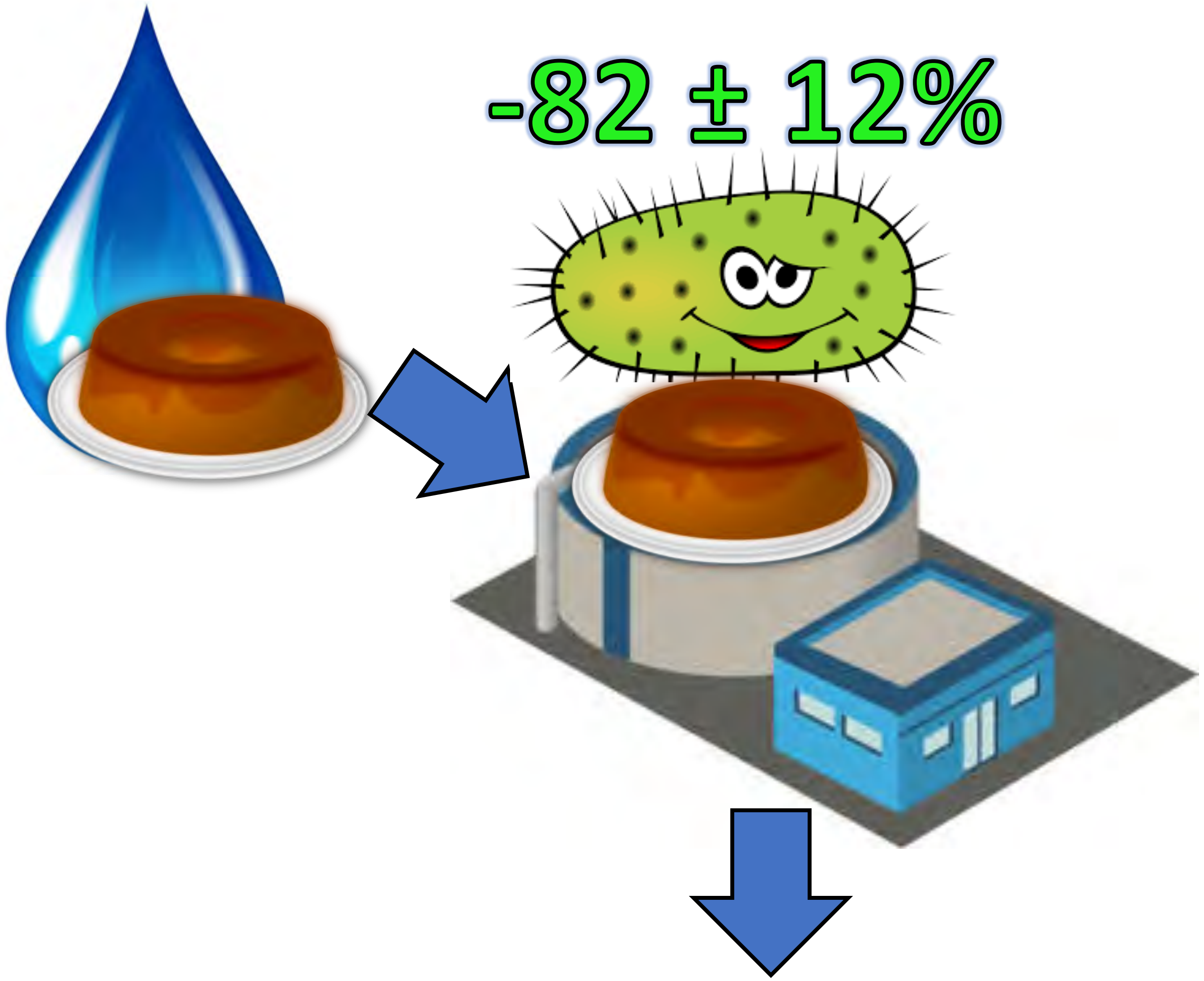
Luo 2014

Lee 2004

NeBRA 2007



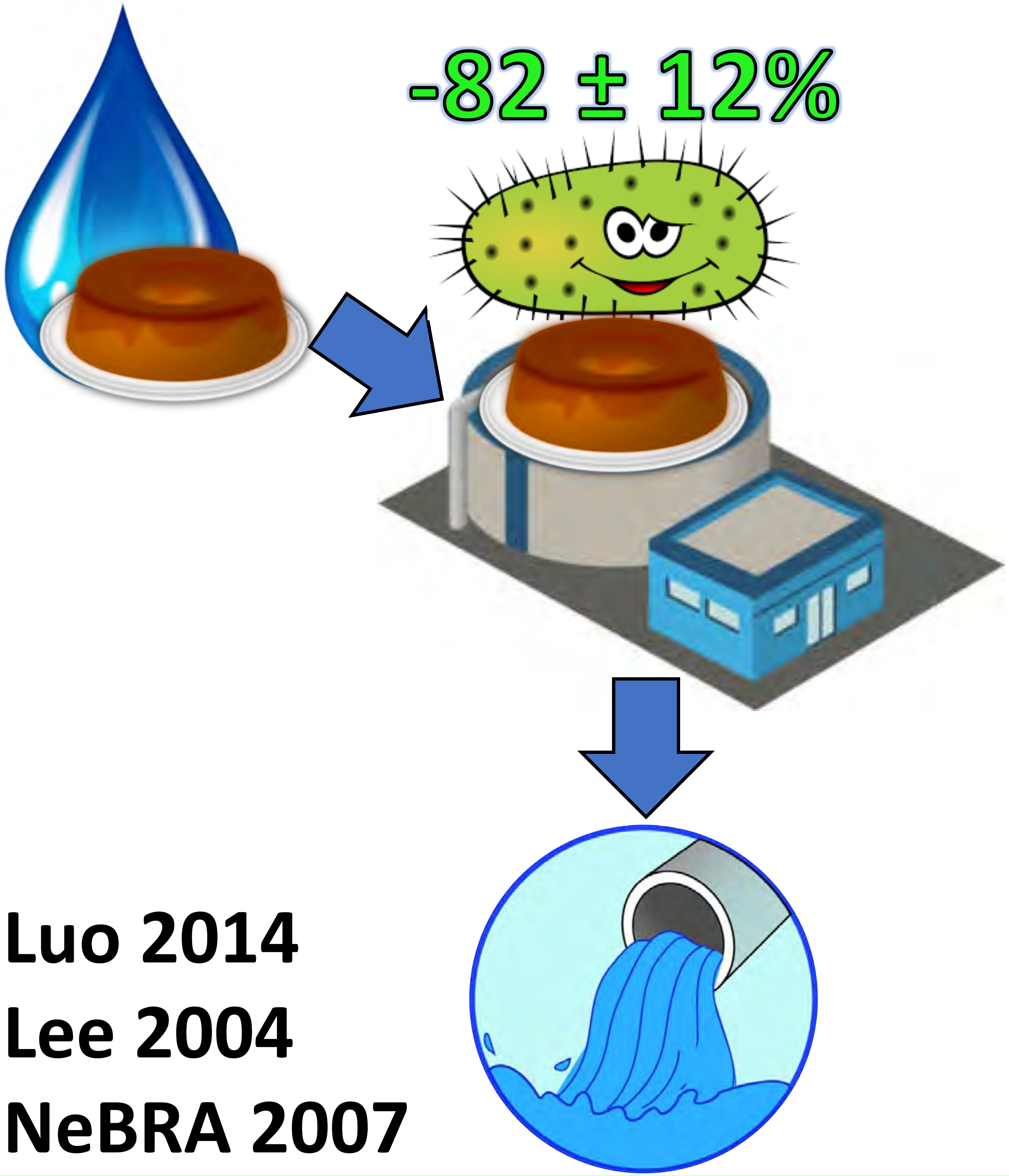
Luo 2014
Lee 2004
NeBRA 2007



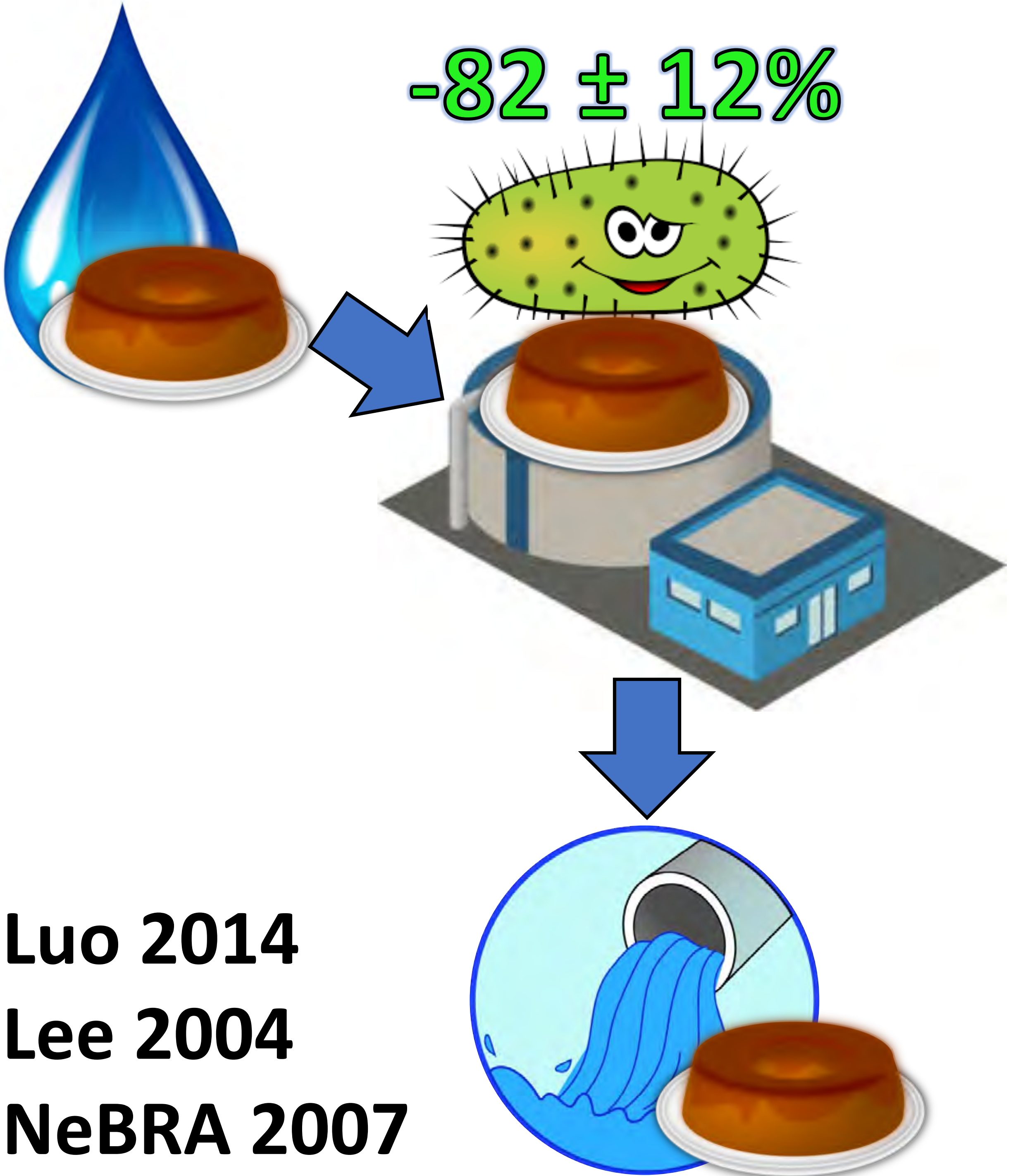
Luo 2014

Lee 2004

NeBRA 2007



Luo 2014
Lee 2004
NeBRA 2007



Luo 2014
Lee 2004
NeBRA 2007

What Are the Concentrations of BPA in WWTP Effluents?

Concentrations of BPA Detected in WWTP Effluents

Country	Year	Range ($\mu g\ L^{-1}$)	Mean ($\mu g\ L^{-1}$)	Ref.
Austria	2000	<0.5–2.5	1.5	Furhacker
Canada	2004	0.01–17.3	—	Lee 2004
EU	2008	3.13–45	—	EU 2008
EU	2008	<0.02–7.6	0.52	Hohne
US	1999	<0.01–2.7	—	Barber 1999

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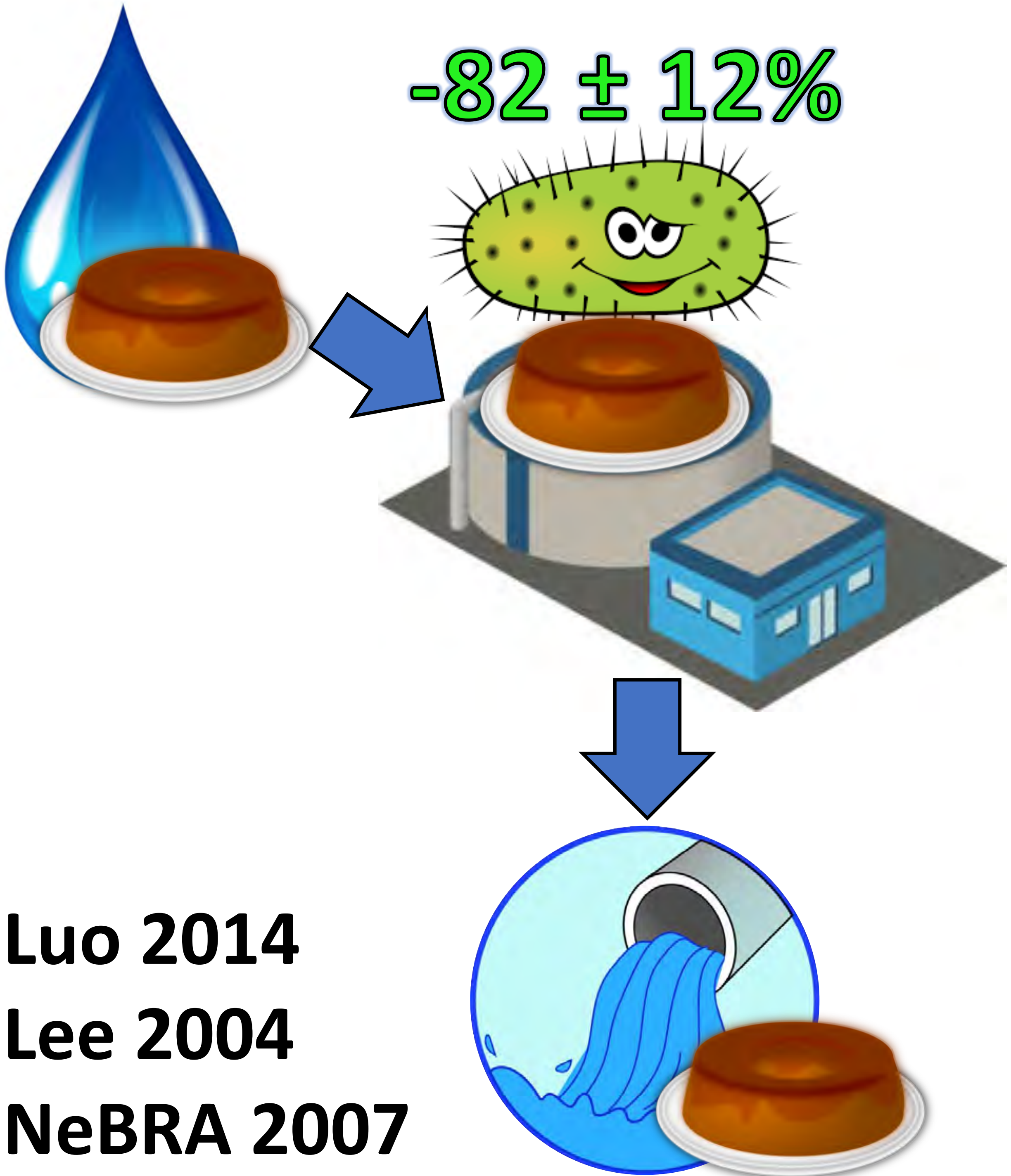
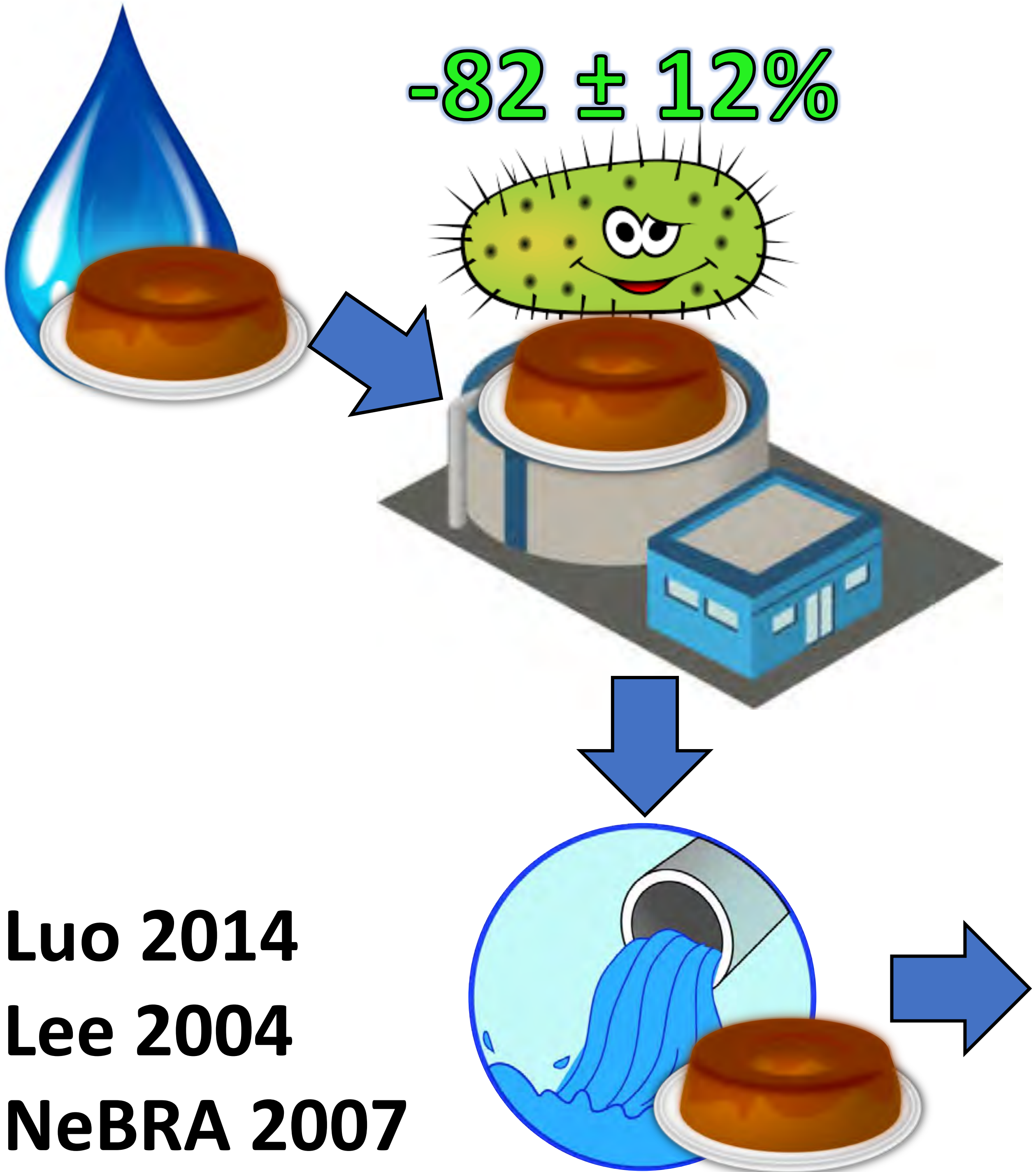


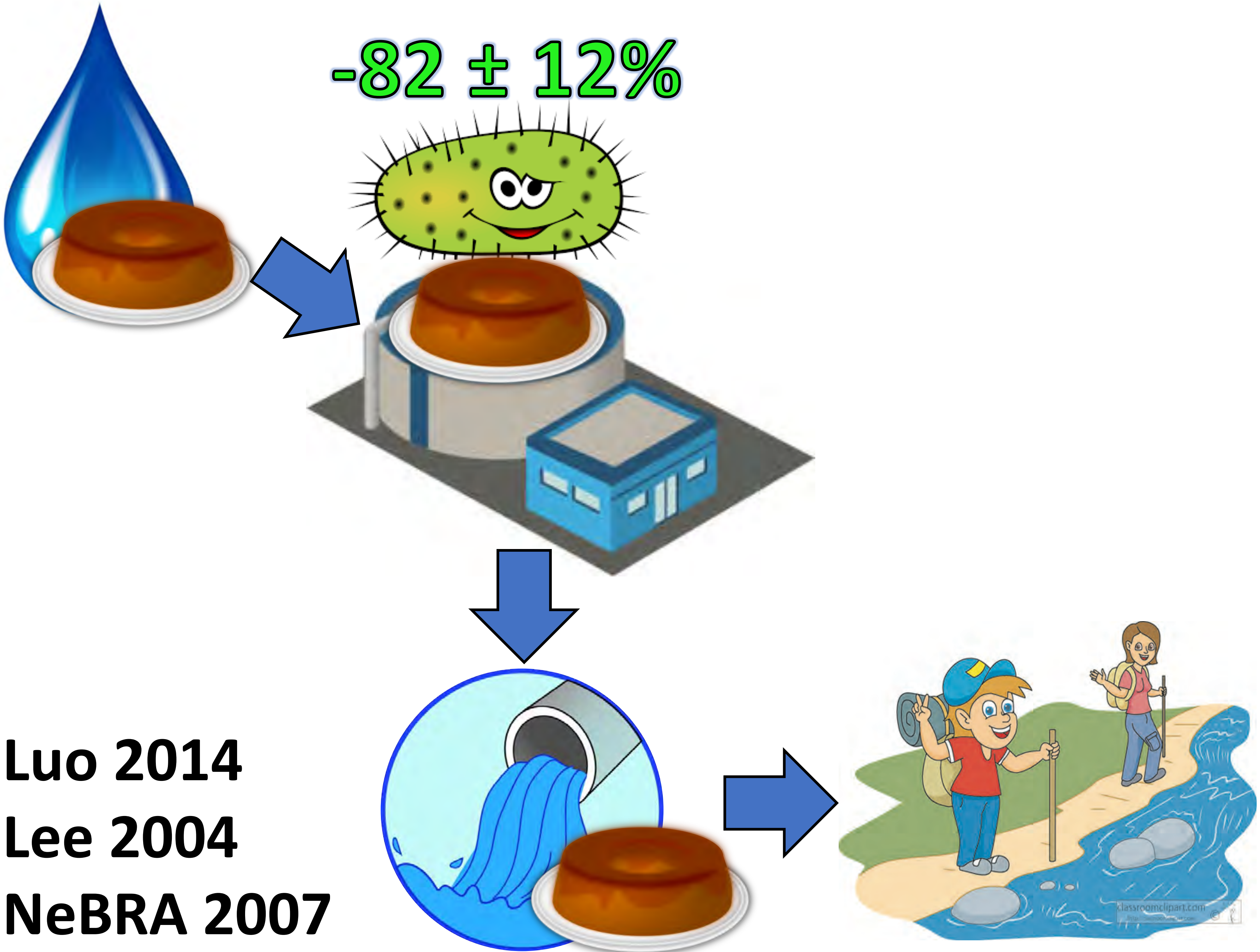
Luo 2014
Lee 2004
NeBRA 2007



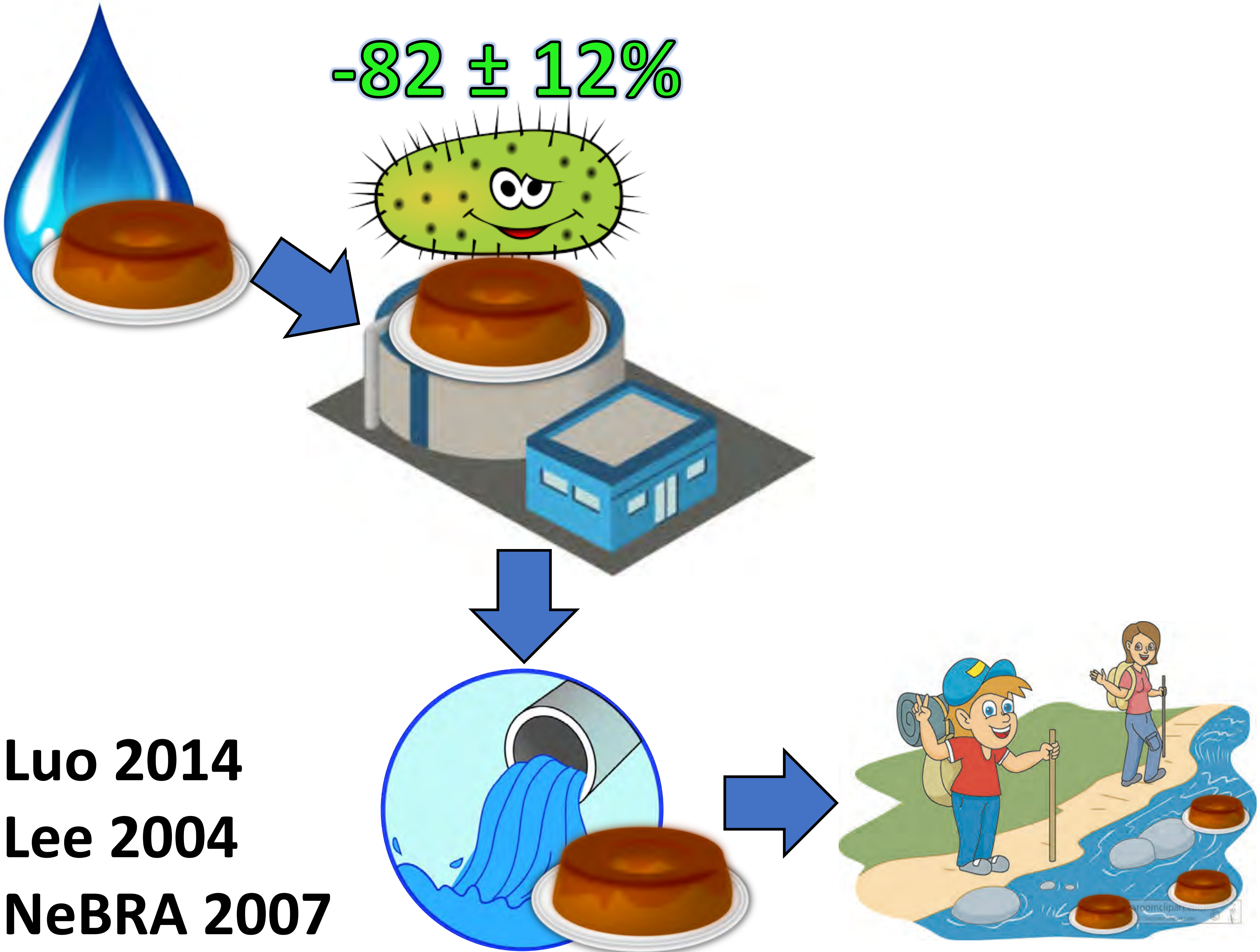
Luo 2014

Lee 2004

NeBRA 2007



Luo 2014
Lee 2004
NeBRA 2007


-82 ± 12%
Luo 2014
Lee 2004
NeBRA 2007

What Are the Concentrations of BPA in Surface Waters?

Surface Water Concentrations of BPA

Country	Watershed	Max ($\mu g\ L^{-1}$)	Median / Avg / Range ($\mu g\ L^{-1}$)	Ref.
US	Multiple	12	Med: 0.14	Kolpin 2002
Brazil	Atibaia	13	Avg: 4.6	Montagner
China	Dongguan	56	Avg: 6.5	Tang 2012
Japan	Nagara	22.2	Avg: 4.8	Funakoshi
Portugal	Multiple	—	Range: 0.07–4	Azevedo 2001

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What Are the Effects of Fish Exposures to These BPA Concentrations?

Embryonic and Early-Life Staged Fish

Metcalfe 2001

Saili 2012

Lee 2012

Wang 2010

Chung 2011

Lam 2011

Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*
- *Decreased Eye Pigmentation Density*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*
- *Decreased Eye Pigmentation Density*
- *Accelerated Development*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*
- *Decreased Eye Pigmentation Density*
- *Accelerated Development*
- *Delayed Hatching of Embryos*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*
- *Decreased Eye Pigmentation Density*
- *Accelerated Development*
- *Delayed Hatching of Embryos*
- *Hyperactivity in Larva*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*
- *Decreased Eye Pigmentation Density*
- *Accelerated Development*
- *Delayed Hatching of Embryos*
- *Hyperactivity in Larva*
- *Testis-Ova in Males*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
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Embryonic and Early-Life Staged Fish

- *Alteration of Gene Expression*
- *Reduction of Heart Rate*
- *Decreased Eye Pigmentation Density*
- *Accelerated Development*
- *Delayed Hatching of Embryos*
- *Hyperactivity in Larva*
- *Testis-Ova in Males*
- *Learning Deficits in Adult Males*

Metcalfe 2001
Saili 2012
Lee 2012
Wang 2010
Chung 2011
Lam 2011
Gibert 2011

Adult Fish

Crain 2007
Sohoni 2001
Lahnsteiner 2005
Hatef 2012
Hayashi 2007
Villenueve 2012
Liu 2012
Qin 2013

Adult Fish

- *Alteration of gene expression including stimulation of vitellogenin synthesis in males (vtg is a precursor of egg yolk protein and is a biomarker for exposure to oestrogens)*

Crain 2007
Sohoni 2001
Lahnsteiner 2005
Hatef 2012
Hayashi 2007
Villenueve 2012
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Adult Fish

- *Alteration of gene expression including stimulation of vitellogenin synthesis in males (vtg is a precursor of egg yolk protein and is a biomarker for exposure to oestrogens)*
- *Reduction in male sperm quality*

Crain 2007
Sohoni 2001
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Hatef 2012
Hayashi 2007
Villenueve 2012
Liu 2012
Qin 2013

Crain 2007
Sohoni 2001
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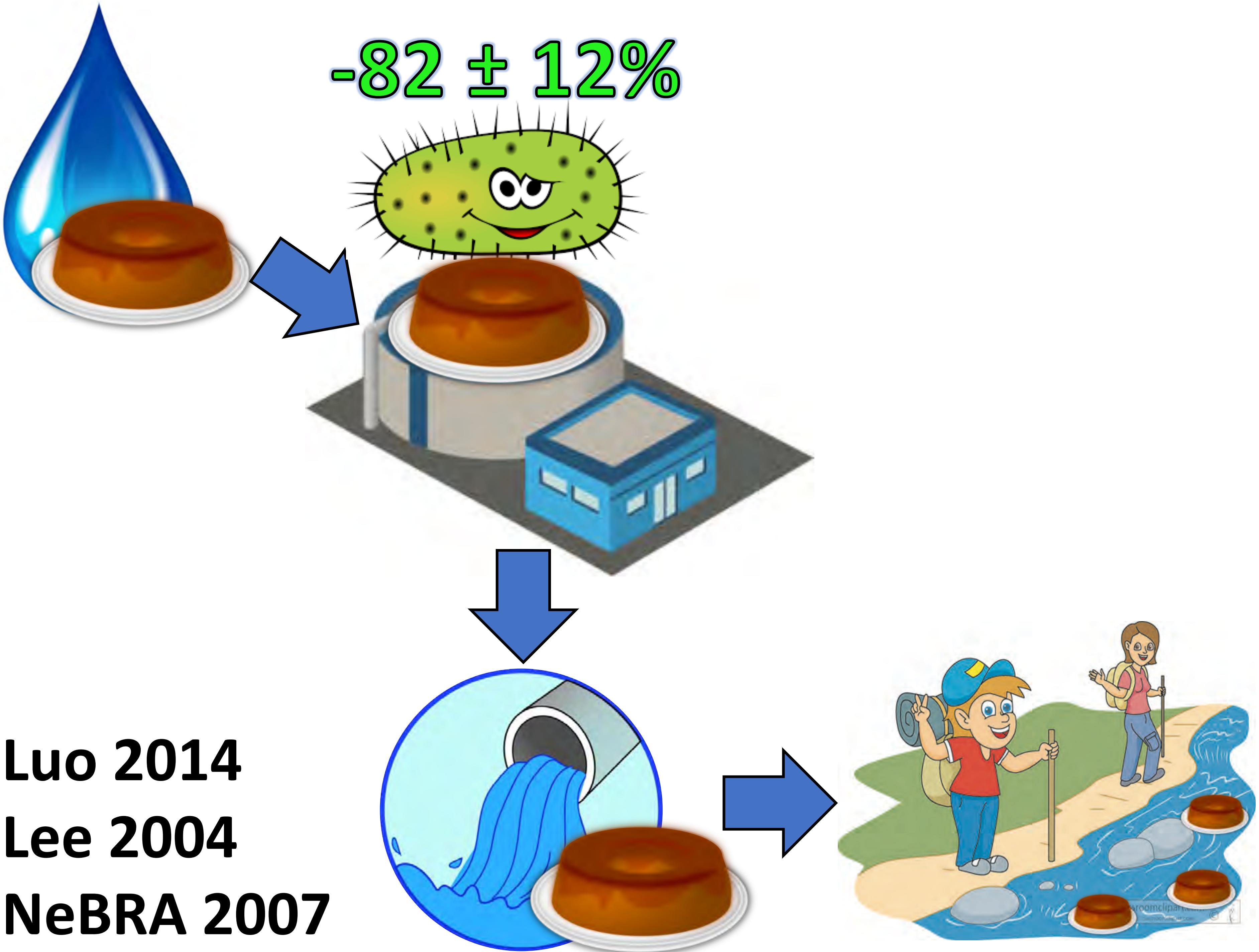
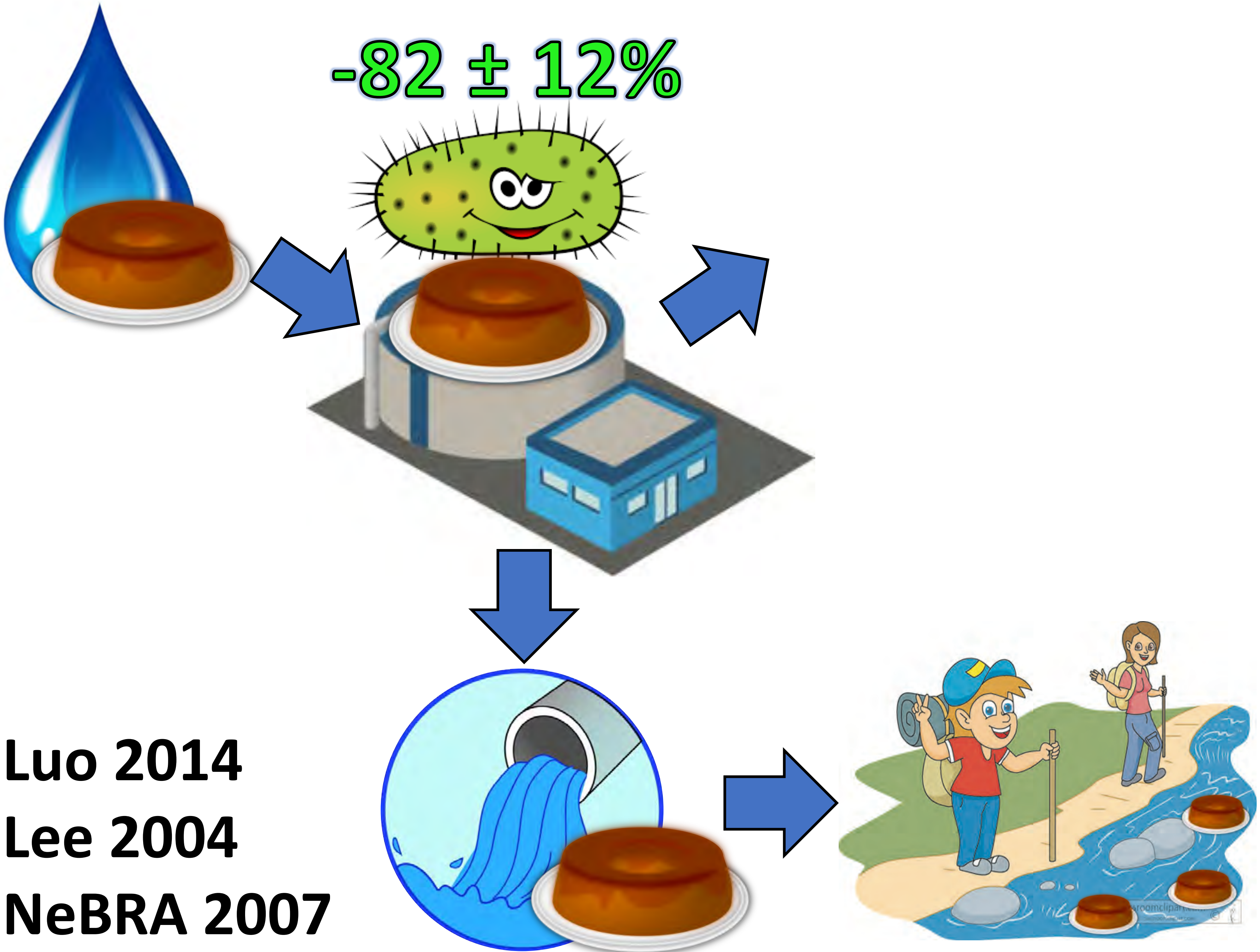
Adult Fish

- *Alteration of gene expression including stimulation of vitellogenin synthesis in males (vtg is a precursor of egg yolk protein and is a biomarker for exposure to oestrogens)*
- *Reduction in male sperm quality*
- *Delayed or no ovulation in females*



Luo 2014
Lee 2004
NeBRA 2007



Luo 2014
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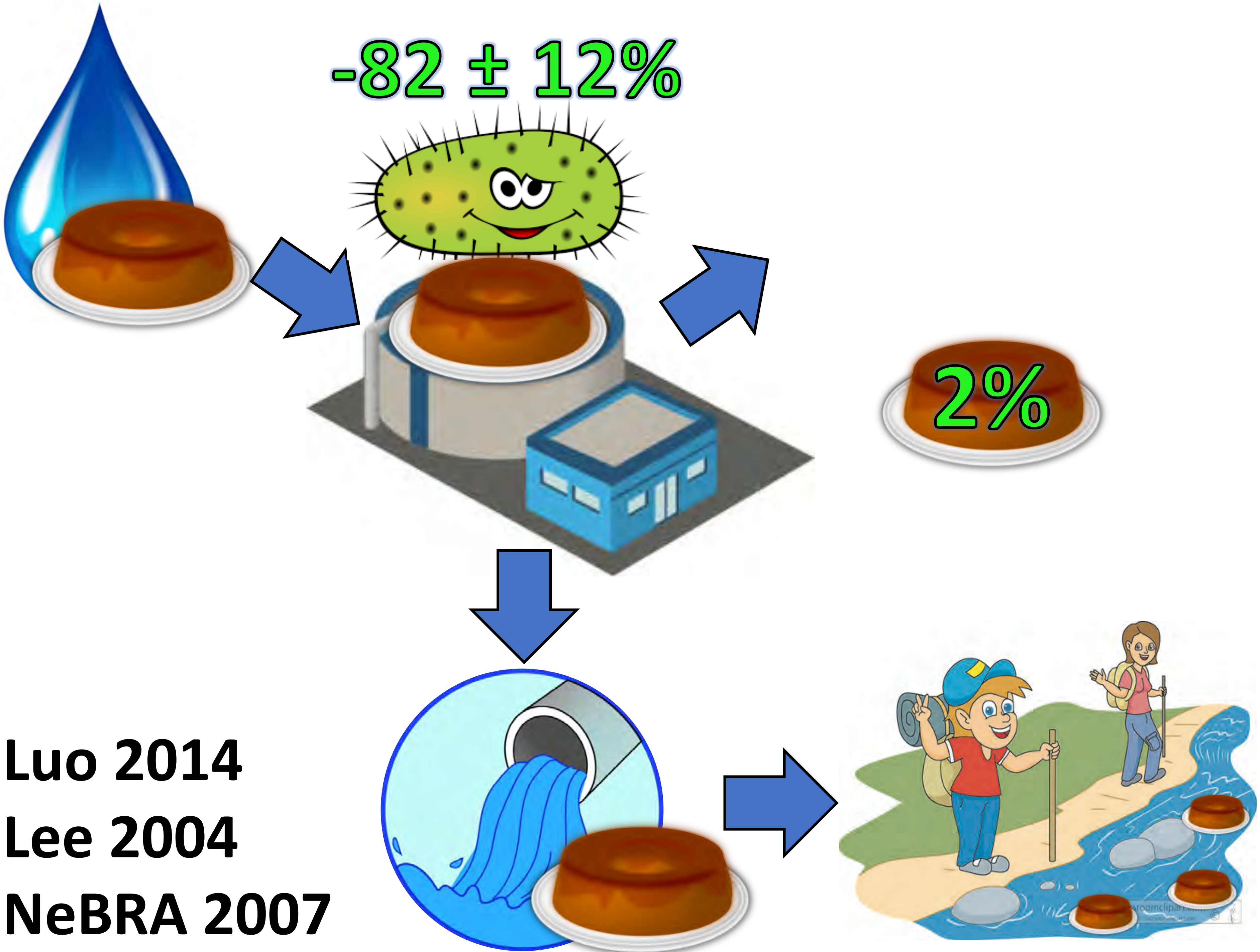
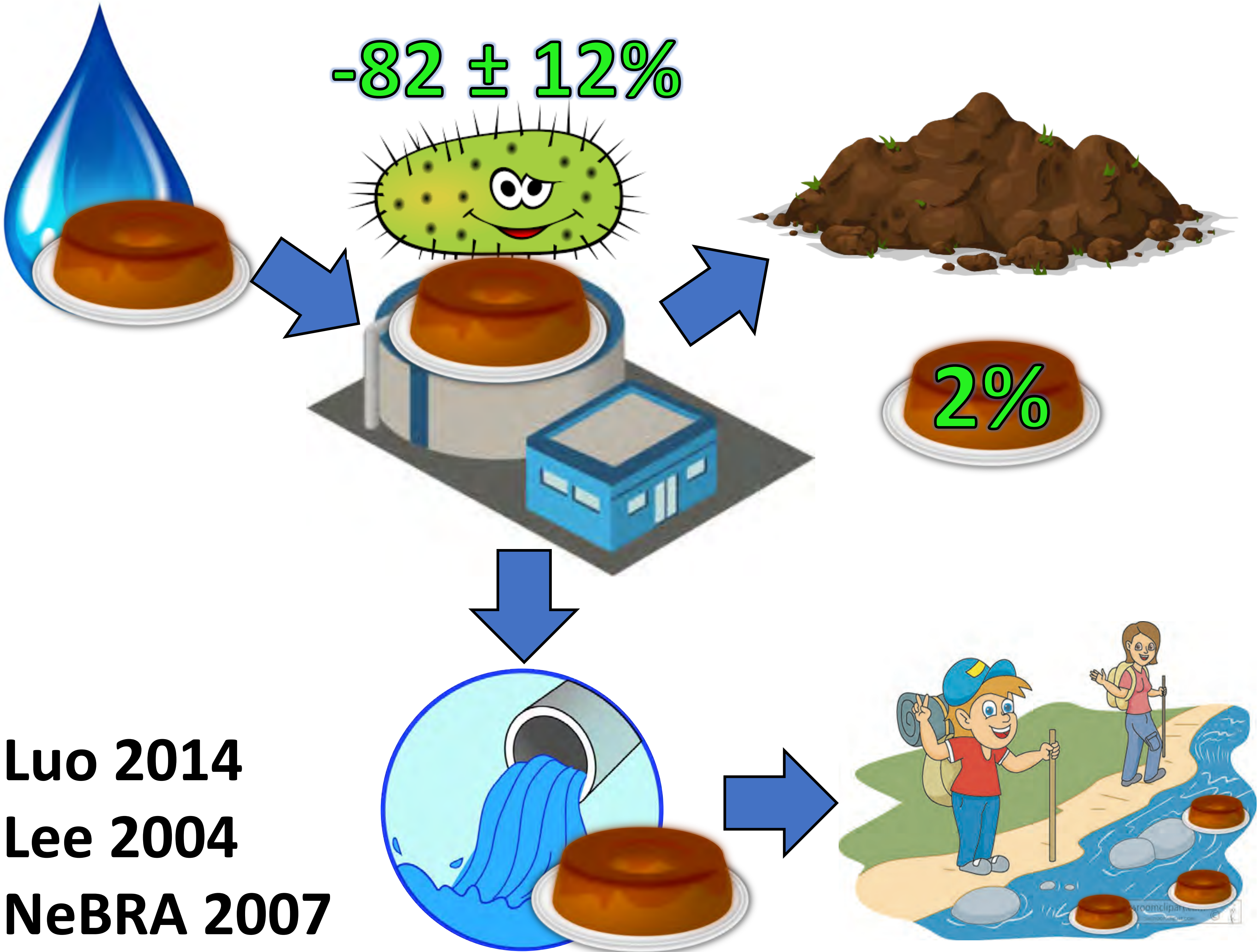
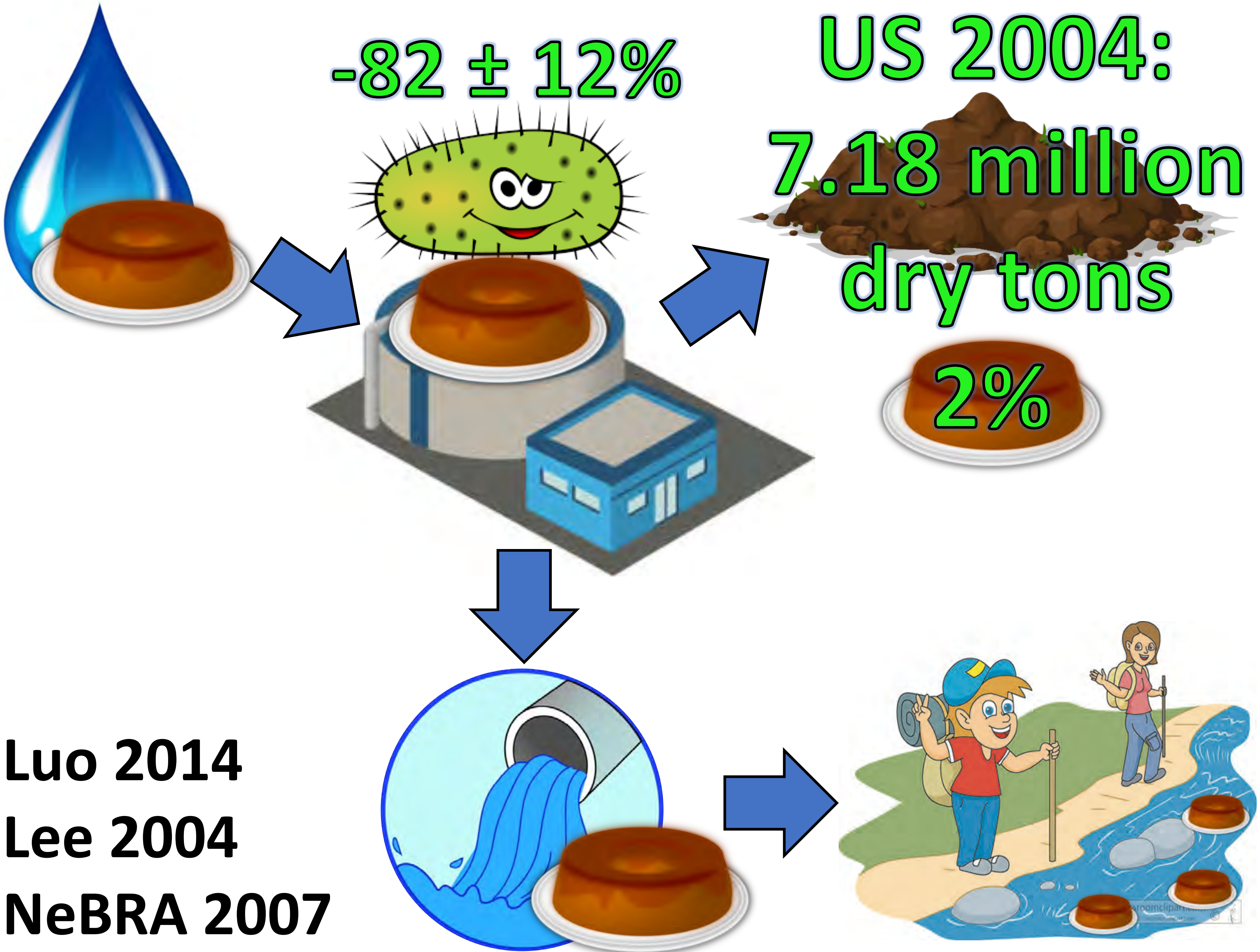

-82 ± 12%
2%
Luo 2014
Lee 2004
NeBRA 2007



Luo 2014
Lee 2004
NeBRA 2007



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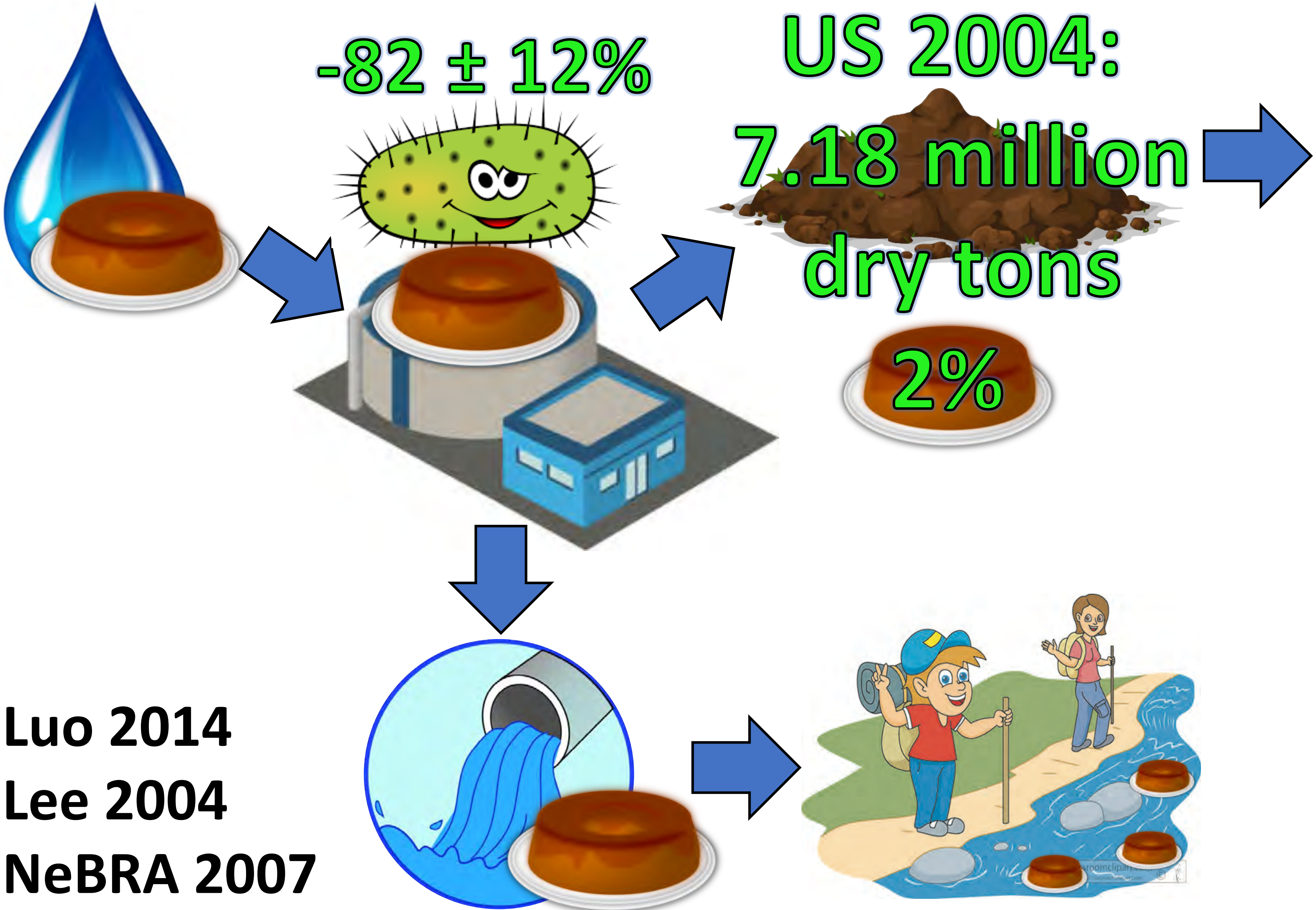

-82 ± 12%
US 2004:
7.18 million
dry tons
2%
Luo 2014
Lee 2004
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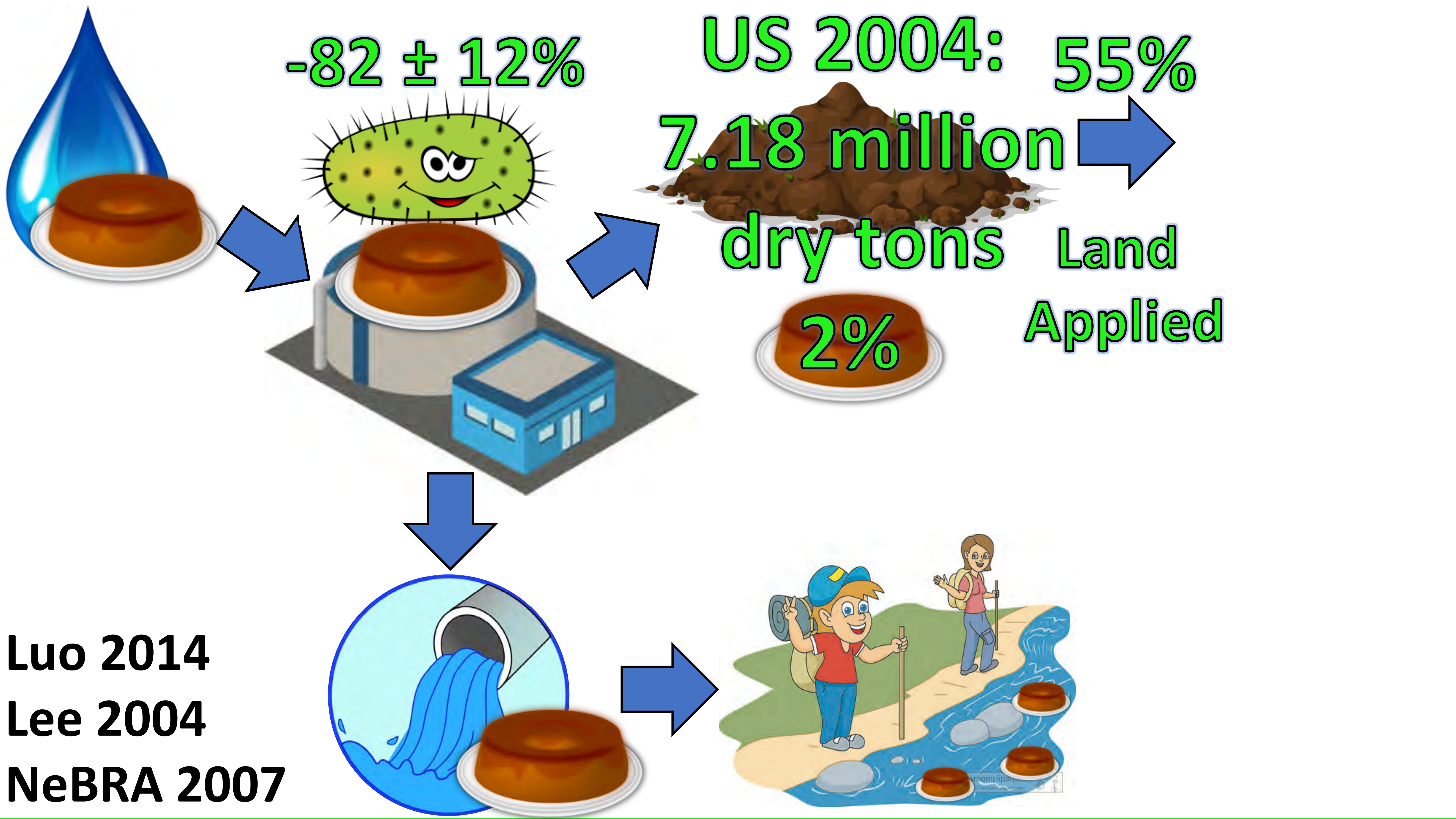
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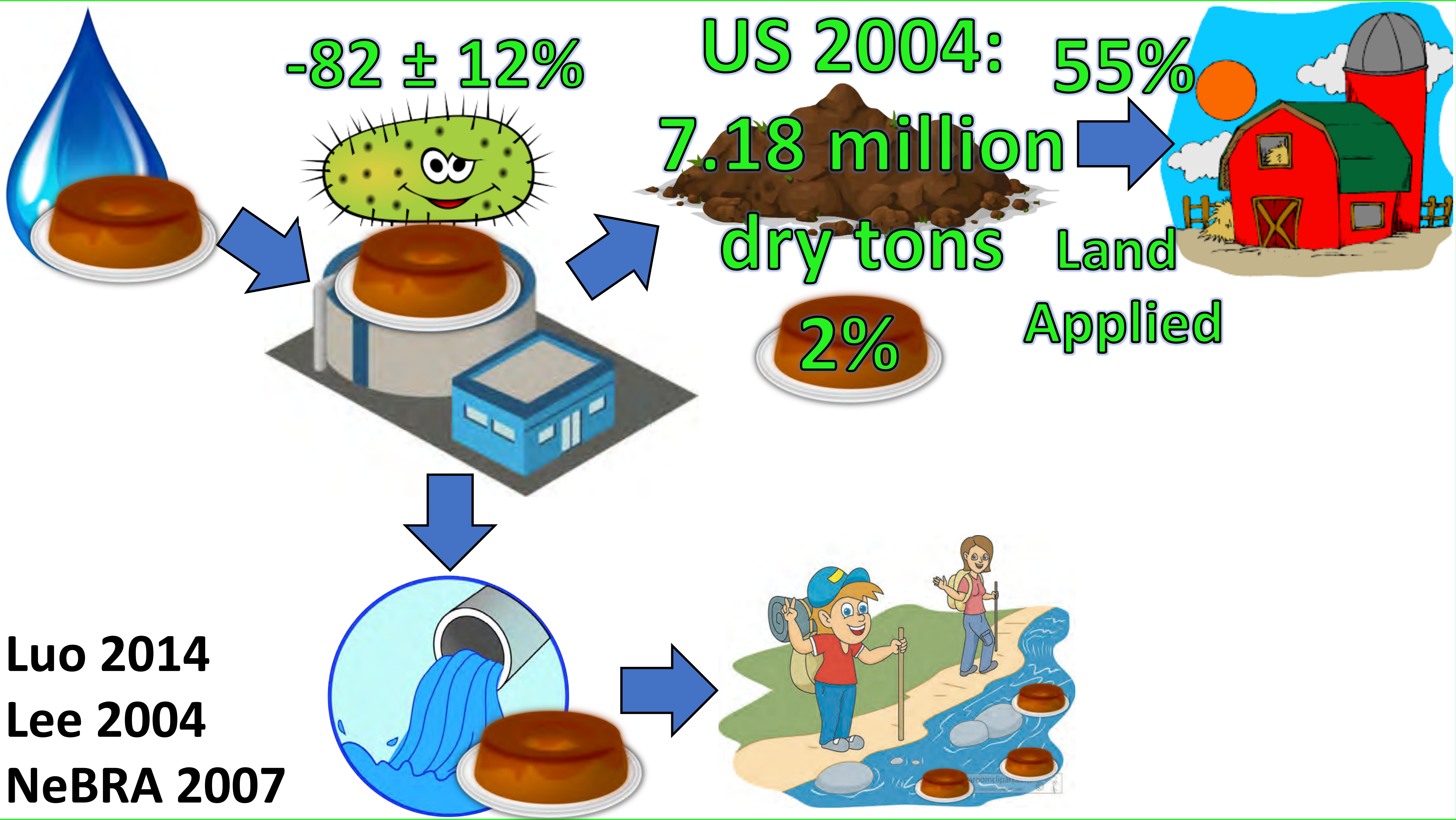
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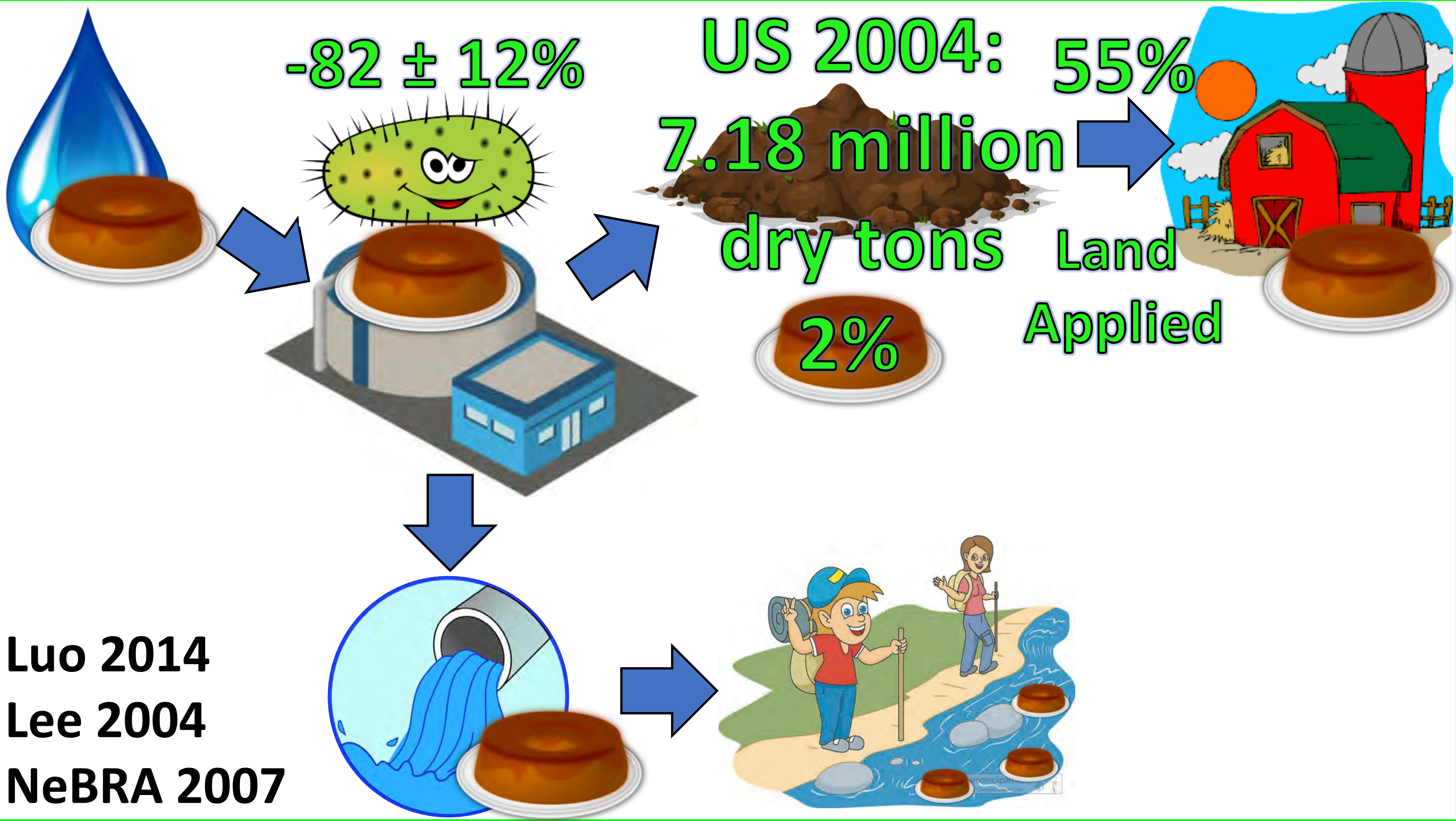

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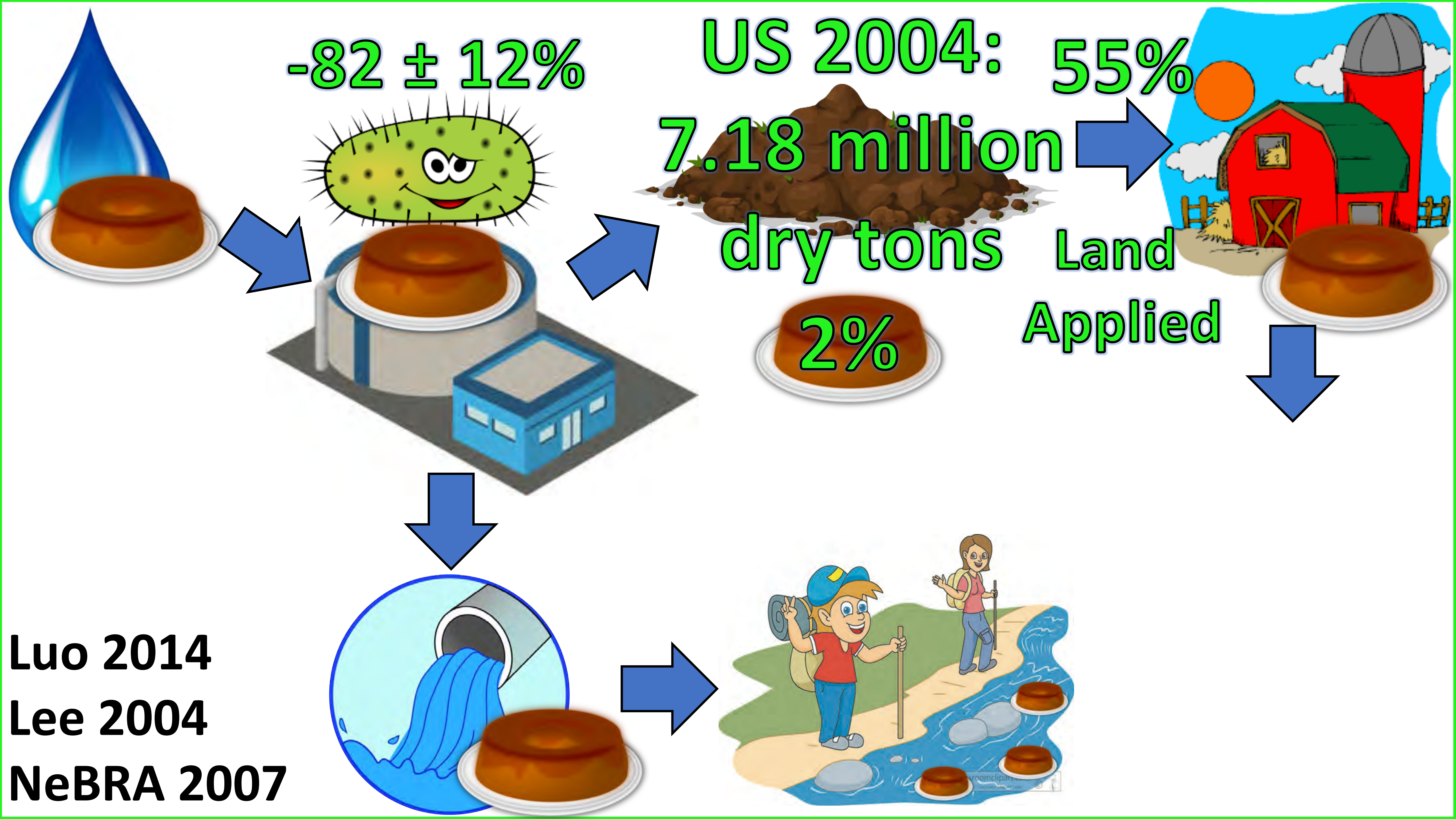
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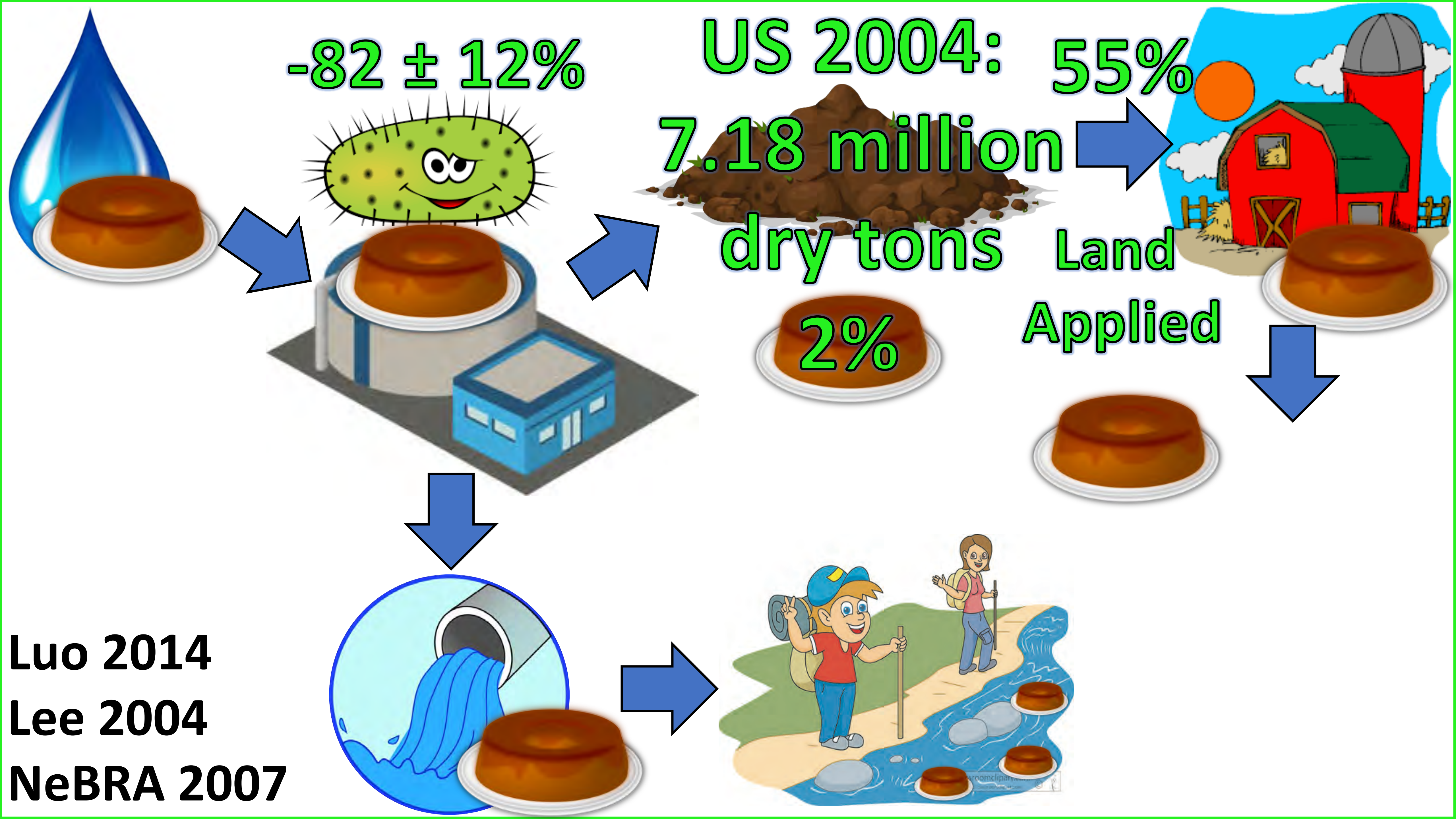
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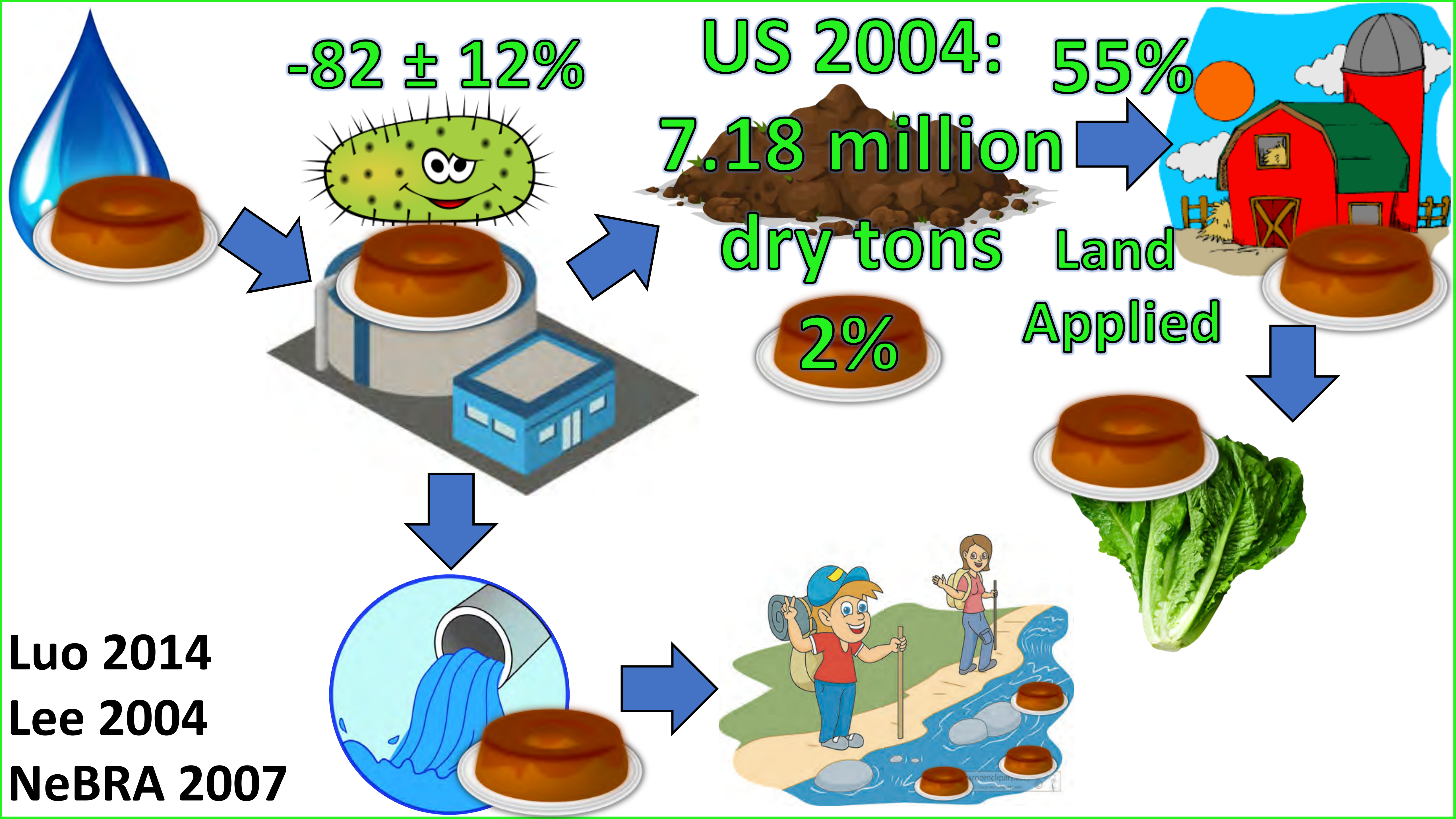
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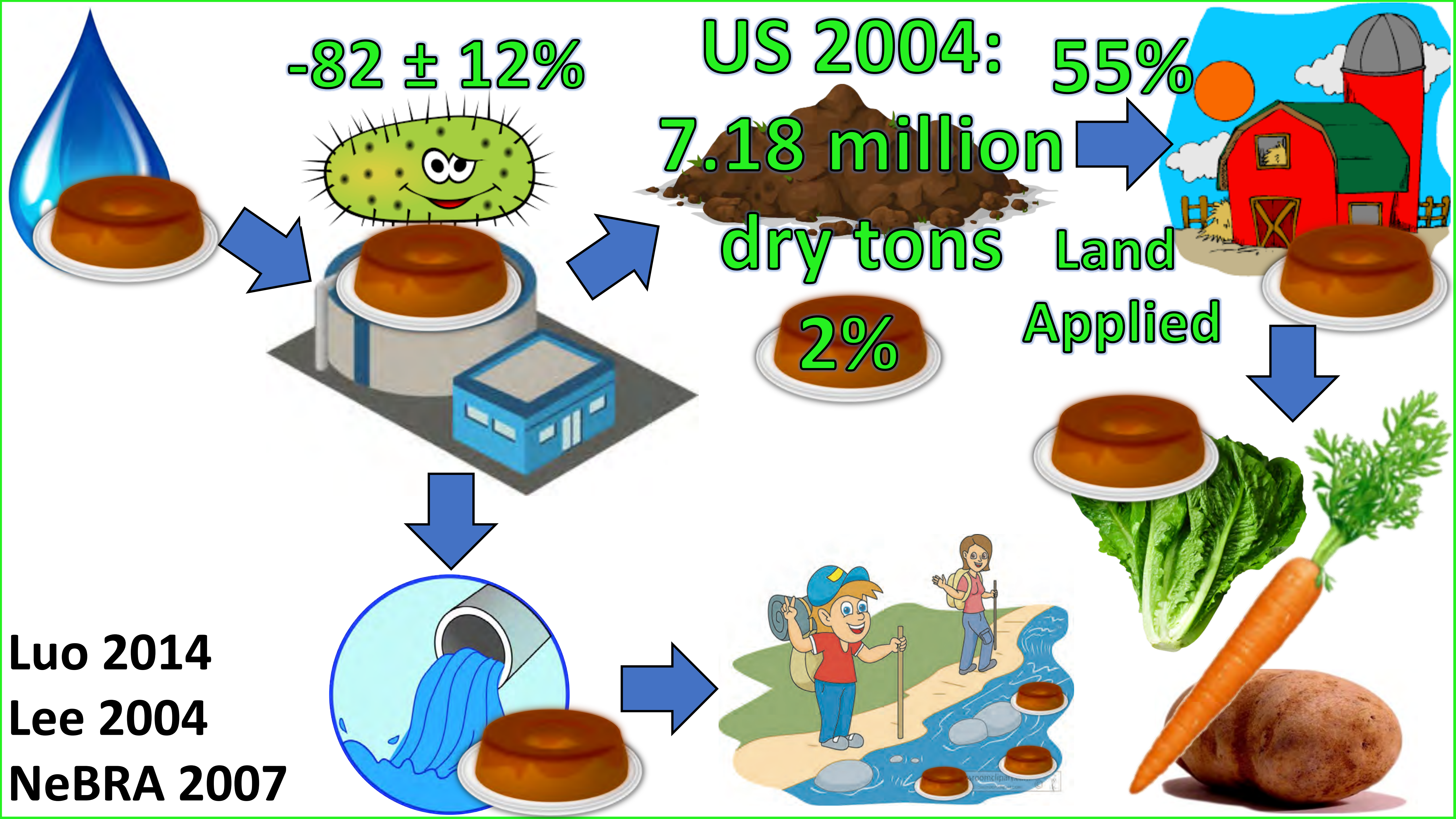
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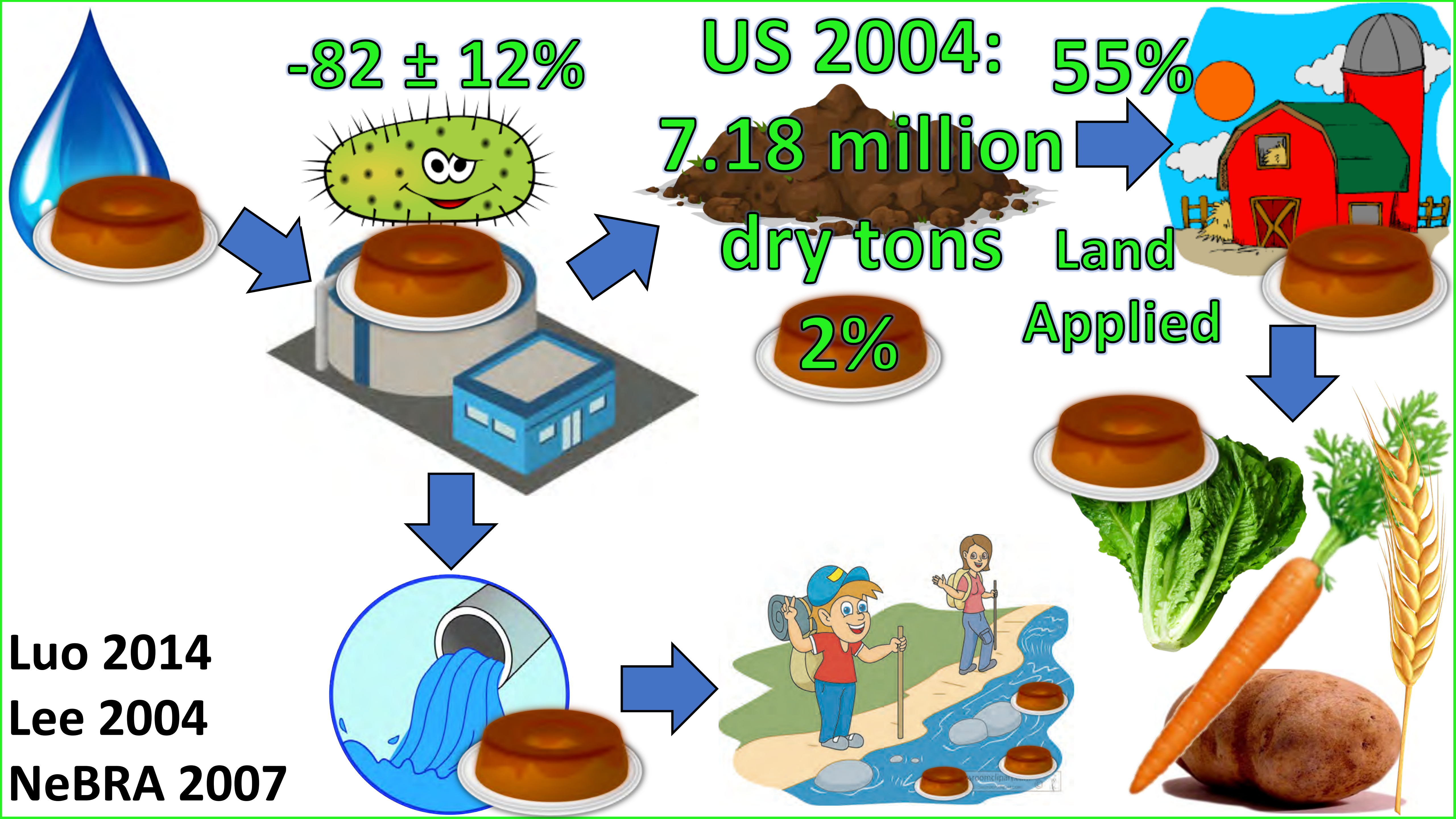
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Production

- *Contamination of Air*
- *Contamination of Water*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

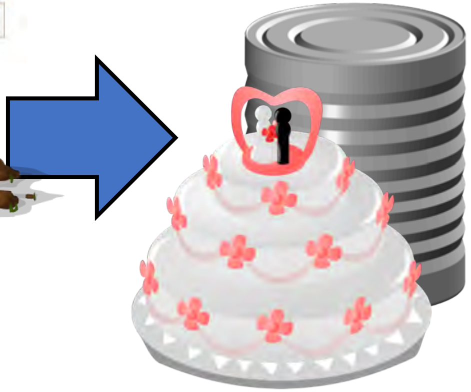
Use

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

Production



Use

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*

Canned Goods: *the liquid phases of canned artichokes, green beans, corn, mushrooms, peas, and mixed vegetables, the homogenized liquid and solid contents of canned fruit products including coconut cream, coconut milk, lychees, mangoes, olives, peaches, light pineapples, tomatoes, tomato juice and tomato paste, and fruit pieces and cocktails, the homogenized liquid and solid contents of canned vegetable products including asparagus, baked beans in tomato sauce, green beans, beetroot, carrots, corn, mount elephants, mushrooms, peas, jalapeño peppers, potatoes, and goulash, the homogenized liquid and solid contents of canned soups including cream of chicken, chicken and white wine, potato, tomato, and Tom Kha, the homogenized liquid and solid contents of canned sauces of many varieties including demi-glace, fond de volaille, gratin, meat, tomato, and white, the homogenized liquid and solid contents of canned pastas in tomato sauce, the homogenized liquid and solid contents of canned seafood including Japanese sand lance, mackerel, pilchards in tomato sauce, salmon, sardine, sardine in tomato sauce shrimp, squid, tuna, and fish and vegetable mixtures, the homogenized liquid and solid contents of canned meats including chicken, corned beef, fish balls, ham, hot dogs, and pork, the homogenized liquid and solid contents of canned quail eggs, the homogenized liquid and solid contents of desserts including evaporated milk and creamed rice, the solids of canned crushed tomatoes, young peas, corn, haricot beans, red kidney beans, lentils, mushrooms, tuna in oil, and sardines in oil, mackerel filet in tomato sauce, and canned dinners.*

Brotons 1995
Braunrath 2005
Thomson 2005
Yonekubo 2008
Goodson 2002
Grumetto 2008
Rastkari 2011
Mungia-Lopez 2002
Maragou 2006
Yoshida 2001
Sakhi 2014

38–67% of all canned goods contain BPA

Canned Goods: *the liquid phases of canned artichokes, green beans, corn, mushrooms, peas, and mixed vegetables, the homogenized liquid and solid contents of can[illegible]d fruit prod[illegible]ts including coconut cre[illegible], [illegible]ut milk, [illegible]chees, m[illegible]go[illegible] [illegible]ves, pea[illegible] [illegible] pine[illegible]es, [illegible]tatoes, tomato juic[illegible] paste and fru[illegible] pieces [illegible]ckt[illegible]s, t[illegible] h[illegible]moge[illegible] li[illegible]i[illegible] and solid contents [illegible] vegetable products includ[illegible]g asparagus, [illegible]ed beans i[illegible] s[illegible]ce, green beans, beetroot, carrots, corn, mount elephants, mushrooms, peas, jalapeño peppers, potatoes, and goulash, the homogenized liquid and solid [illegible]ntents of canned soups includi[illegible] cream of chicken, chicken [illegible] [illegible]d [illegible] [illegible] [illegible]and [illegible] [illegible] [illegible]d and solid content[illegible] of [illegible] s[illegible] [illegible] [illegible]ding [illegible] [illegible], meat, tomato, and white, the homogenized liquid and solid [illegible]ts of canned pastas in tomato sauce, the homogenized liquid and solid contents of ca[illegible]ed seafood i[illegible] [illegible] and lance, mackerel, pilch[illegible] [illegible] [illegible]dine [illegible] [illegible]mp, squid, tuna, and fish [illegible] [illegible] canned meats including [illegible], [illegible] [illegible], [illegible], hot dogs, [illegible] pork, the homogenized liquid and solid contents of canned quail eggs, the homogenized liquid and solid contents of desserts including evaporated milk and creamed rice, the solids of canned crushed tomatoes, young peas, corn, haricot beans, red kidney beans, lentils, mushrooms, tuna in oil, and sardines in oil, mackerel filet in tomato sauce, and canned dinners.*

Cox 2017

Canned Goods: *the liquid phases of canned artichokes, green beans, corn, mushrooms, peas, and mixed vegetables, the homogenized liquid and solid contents of canned fruit products including coconut cream, coconut milk, [illegible], [illegible], peaches, pineapples, tomatoes, tomato juice, [illegible] pieces [illegible], the homogenized liquid and solid contents of canned vegetable products including asparagus, baked beans in tomato sauce, green beans, beetroot, carrots, corn, mount elephants, mushrooms, peas, jalapeño peppers, potatoes, and goulash, the homogenized liquid and solid contents of canned soups including cream of chicken, [illegible], the homogenized liquid and solid contents of canned sauces of many varieties including [illegible], meat, tomato, and white, the homogenized liquid and solid contents of canned pastas in tomato sauce, the homogenized liquid and solid contents of canned seafood including [illegible] and lance, mackerel, pilchards [illegible], sardines [illegible], shrimp, squid, tuna, and fish and vegetable mixtures, the homogenized liquid and solid contents of canned meats including chicken, corned beef, fish balls, ham, hot dogs, and pork, the homogenized liquid and solid contents of canned quail eggs, the homogenized liquid and solid contents of desserts including evaporated milk and creamed rice, the solids of canned crushed tomatoes, young peas, [illegible], mackerel filet in tomato sauce, and canned dinners.*

38–67% of all canned goods contain BPA

but beyond canned foods…

Cox 2017

Unexpected Foods

Basheer 2004, Sakhi 2014

Vivacqua 2003, Cao 2009

Unexpected Foods

- *baby food products in glass jars with metal lids*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009


Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014

Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*

Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*

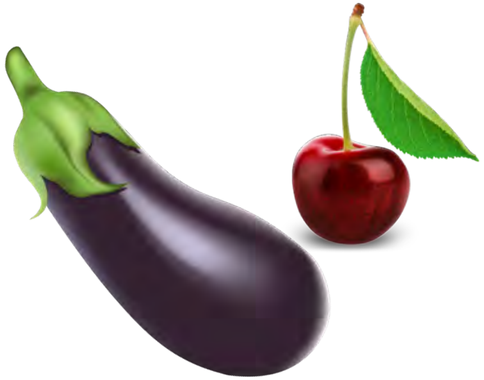
Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*



Unexpected Foods

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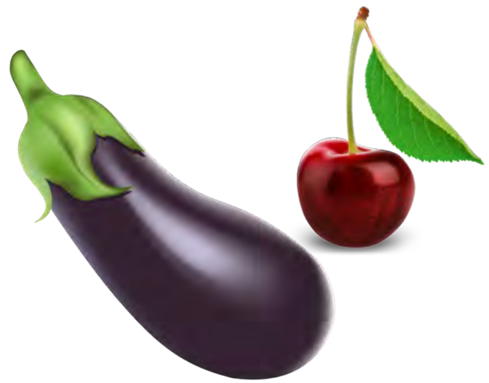
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*



Unexpected Foods

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- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*

Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
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- *peppers*

Unexpected Foods

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Basheer 2004, Sakhi 2014
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Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Unexpected Foods

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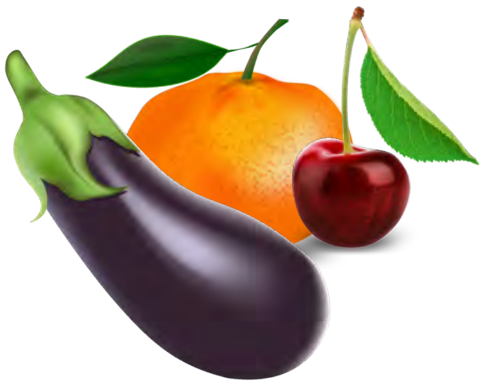
- *whole eggs packaged in cardboard*

Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

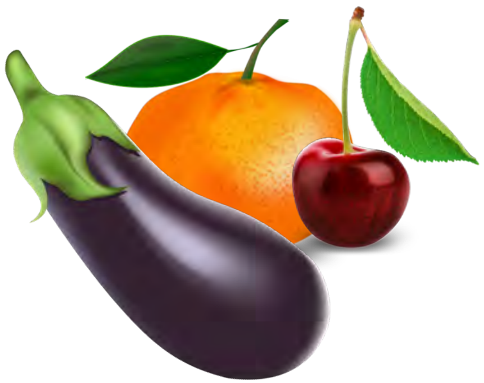
Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009


Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods

- *white clams*



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

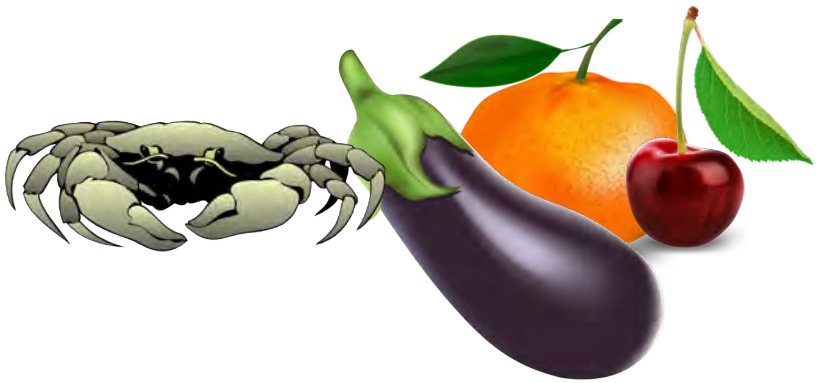
Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods

- *white clams*
- *crabs*



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

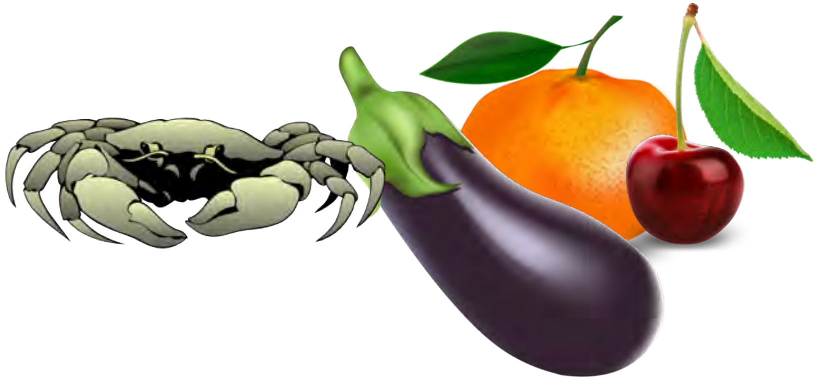
Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods

- *white clams*
- *crabs*
- *blood cockles*



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

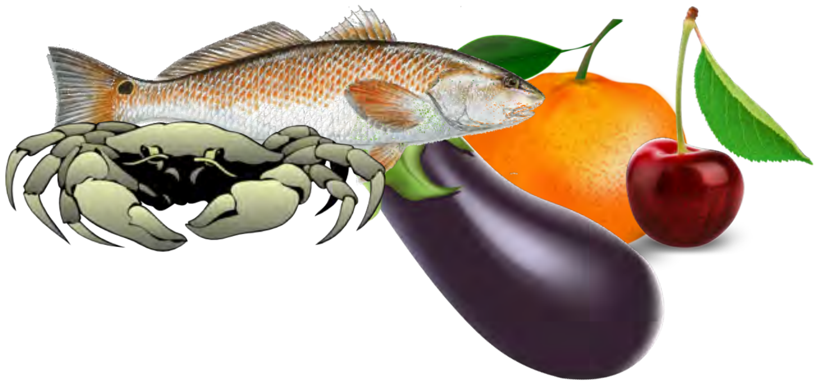
Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods

- *white clams*
- *crabs*
- *blood cockles*
- *fish*



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

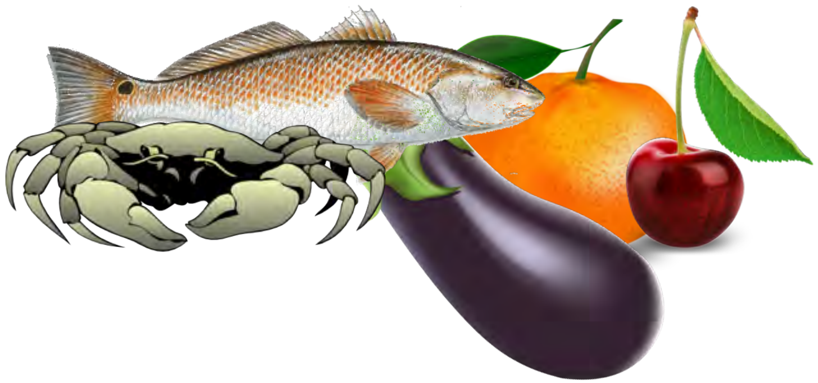
Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods

- *white clams*
- *crabs*
- *blood cockles*
- *fish*
- *prawn*



Unexpected Foods

- *baby food products in glass jars with metal lids*
- *whole eggs packaged in cardboard*

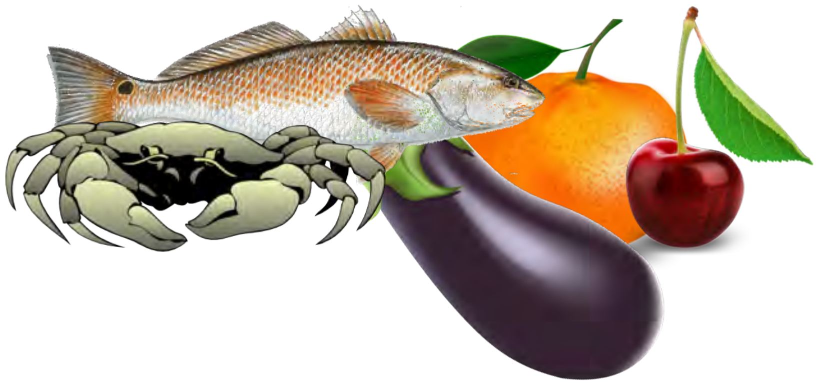
Basheer 2004, Sakhi 2014
Vivacqua 2003, Cao 2009

Randomly Selected Fresh Foods

- *fresh cherries*
- *courgettes*
- *eggplants*
- *medlars*
- *oranges*
- *peaches*
- *peppers*
- *tomatoes*

Seafoods

- *white clams*
- *crabs*
- *blood cockles*
- *fish*
- *prawn*
- *squid*



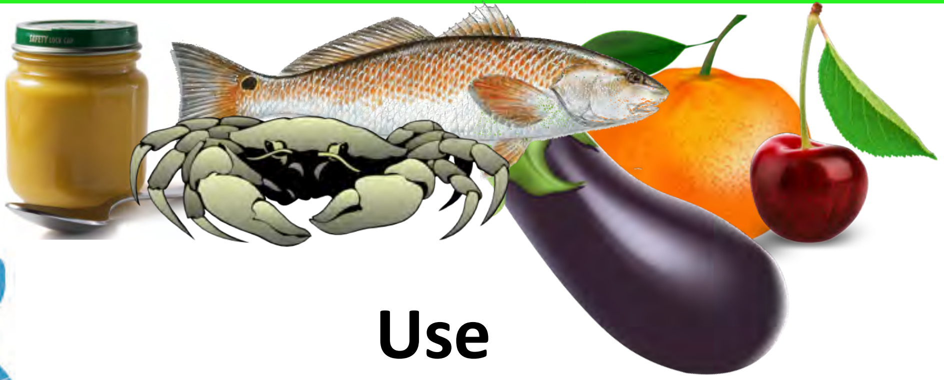
Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*

Production

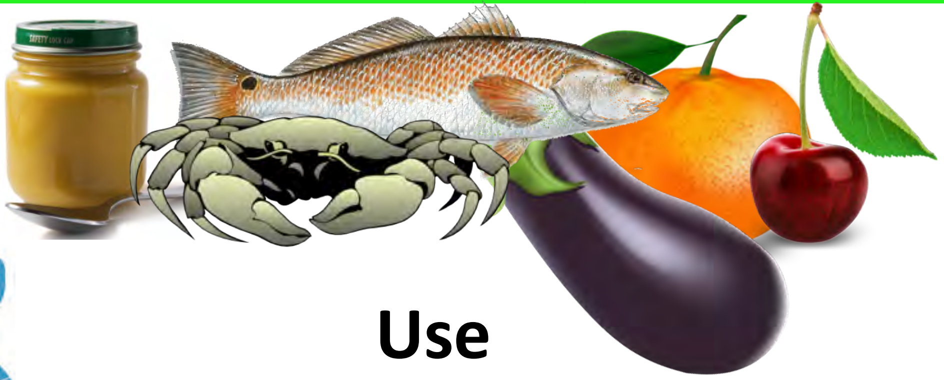


Use

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*

Production



Use

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*

Canned Beverages

Tateoka 2014,
Braunrath 2005,
Takao 1999, Kang 2002

Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*

Tateoka 2014,
Braunrath 2005,
Takao 1999, Kang 2002

Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- *decaffeinated and non-decaffeinated coffees*

Tateoka 2014,
Braunrath 2005,
Takao 1999, Kang 2002

Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- *decaffeinated and non-decaffeinated coffees*
- *soft drinks including diet and regular ginger ales*

Tateoka 2014, Braunrath 2005, Takao 1999, Kang 2002

Cao 2009, Sakhi 2014, Biles 1997, Ackerman 2010, Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- *decaffeinated and non-decaffeinated coffees*
- *soft drinks including diet and regular ginger ales*
- *diet and regular root beers*

Tateoka 2014,
Braunrath 2005,
Takao 1999, Kang 2002

Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- *decaffeinated and non-decaffeinated coffees*
- *soft drinks including diet and regular ginger ales*
- *diet and regular root beers*
- *diet and regular colas*

Tateoka 2014, Braunrath 2005, Takao 1999, Kang 2002

Cao 2009, Sakhi 2014, Biles 1997, Ackerman 2010, Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- *decaffeinated and non-decaffeinated coffees*
- *soft drinks including diet and regular ginger ales*
- *diet and regular root beers*
- *diet and regular colas*
- *energy drinks*

Tateoka 2014, Braunrath 2005, Takao 1999, Kang 2002

Cao 2009, Sakhi 2014, Biles 1997, Ackerman 2010, Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- *decaffeinated and non-decaffeinated coffees*
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- *diet and regular root beers*
- *diet and regular colas*
- *energy drinks*
- *orange and lemon soft drinks*

Tateoka 2014,
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Takao 1999, Kang 2002

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- *diet and regular colas*
- *energy drinks*
- *orange and lemon soft drinks*
- *flavoured and unflavoured soda waters*

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Braunrath 2005,
Takao 1999, Kang 2002

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- *orange and lemon soft drinks*
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- *teas and tonic waters*
- *infant and follow up formulas*

Tateoka 2014,
Braunrath 2005,
Takao 1999, Kang 2002

Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
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Canned Beverages

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Braunrath 2005,
Takao 1999, Kang 2002**

**Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
Cao 2008, Kuo 2004**

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- *flavoured and unflavoured soda waters*
- *teas and tonic waters*
- *infant and follow up formulas*

6.2 µg L^{-1} of BPA
in her breastmilk

<u>Tateoka 2014,</u>
Braunrath 2005,
Takao 1999, Kang 2002

Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
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- *canned beers*
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- *teas and tonic waters*
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6.2 µg L^{-1} of BPA in her breastmilk

37.4 µg

Tateoka 2014, Braunrath 2005, Takao 1999, Kang 2002

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1 h

<u>**Tateoka 2014,**</u>
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- *flavoured and unflavoured soda waters*
- *teas and tonic waters*
- *infant and follow up formulas*

6.2 µg L^{-1} of BPA in her breastmilk

37.4 µg

1 h

ca. 30 µg L^{-1} of BPA in her breastmilk

<u>Tateoka 2014,</u> Braunrath 2005, Takao 1999, Kang 2002

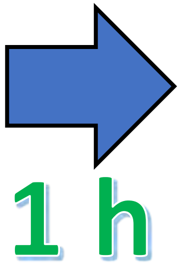
Cao 2009, Sakhi 2014, Biles 1997, Ackerman 2010, Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- ***decaffeinated and non-decaffeinated coffees***
- *soft drinks including diet and regular ginger [illegible]s*
- *diet [illegible]lar root beers*
- *die[illegible]r colas*

- *energy drinks*
- *orange and lemon soft drinks*
- *flavoured and unflavoured soda waters*
- *teas and tonic waters*
- *infant and follow up formulas*

6.2 µg L^{-1} of BPA in her breastmilk



ca. 30 µg L^{-1} of BPA in her breastmilk

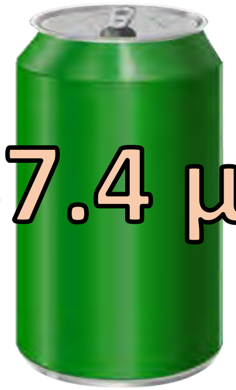
Tateoka 2014, Braunrath 2005, Takao 1999, Kang 2002

Cao 2009, Sakhi 2014, Biles 1997, Ackerman 2010, Cao 2008, Kuo 2004

Canned Beverages

- *canned beers*
- ***decaffeinated and non-decaffeinated coffees***
- *soft drinks including diet and regular ginger s*
- *diet ar root beers*
- *die r colas*
- *energy drinks*
- *orange and lemon soft drinks*
- *flavoured and unflavoured soda waters*
- *teas and tonic waters*
- ***infant and follow up formulas***

6.2 µg L^{-1} of BPA in her breastmilk



1 h

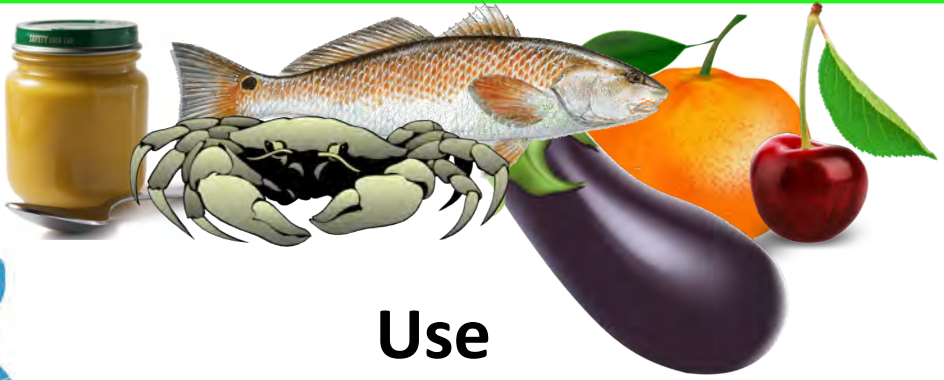
ca. 30 µg L^{-1} of BPA in her breastmilk

<u>Tateoka 2014,</u>
Braunrath 2005,
Takao 1999, Kang 2002

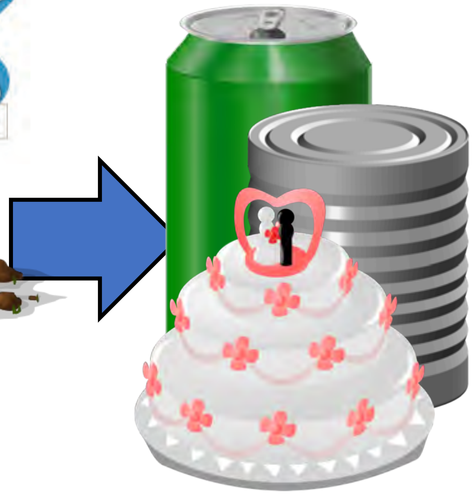
Cao 2009, Sakhi 2014,
Biles 1997, Ackerman 2010,
Cao 2008, Kuo 2004

Production

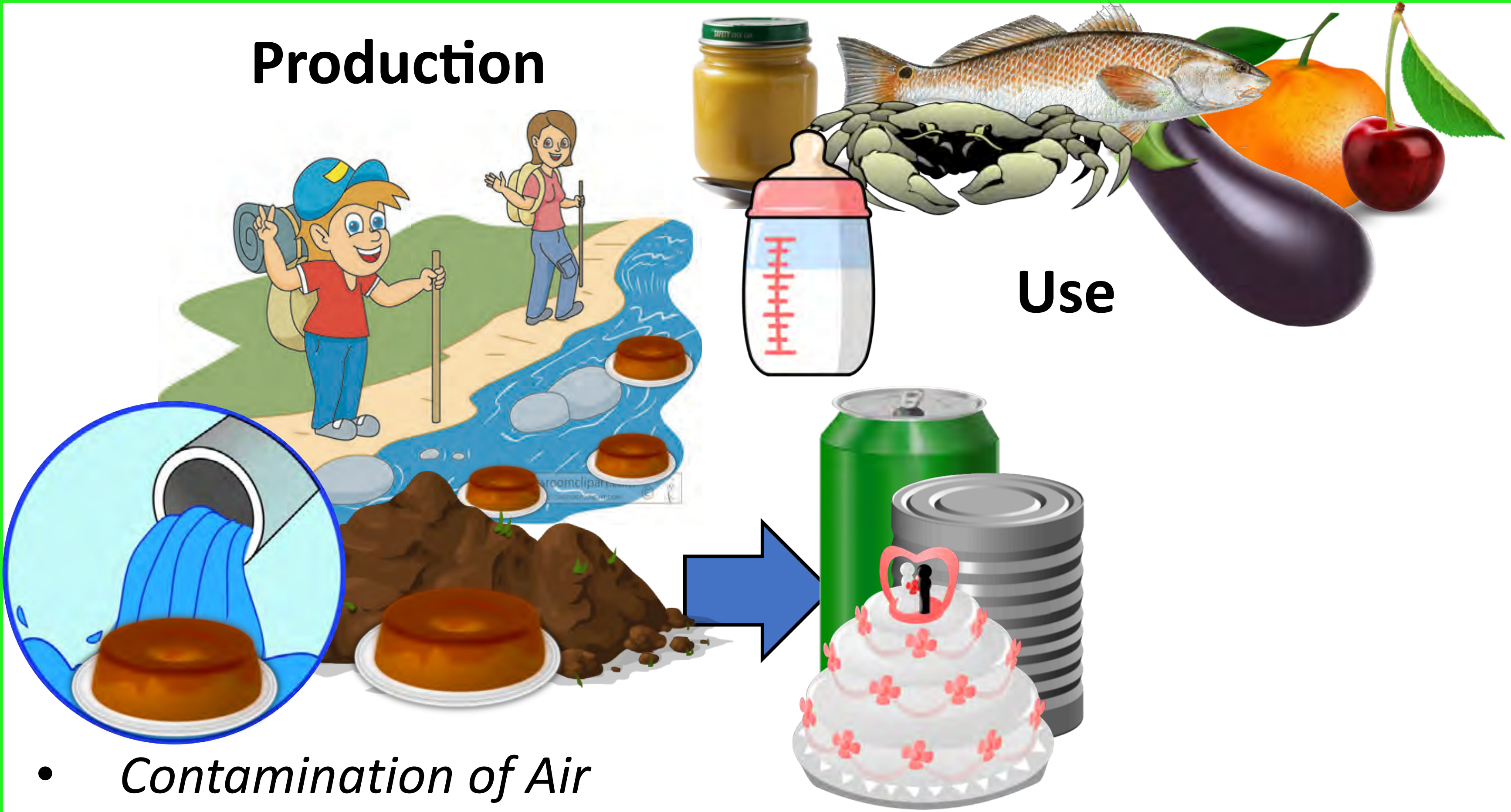
- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*



Use

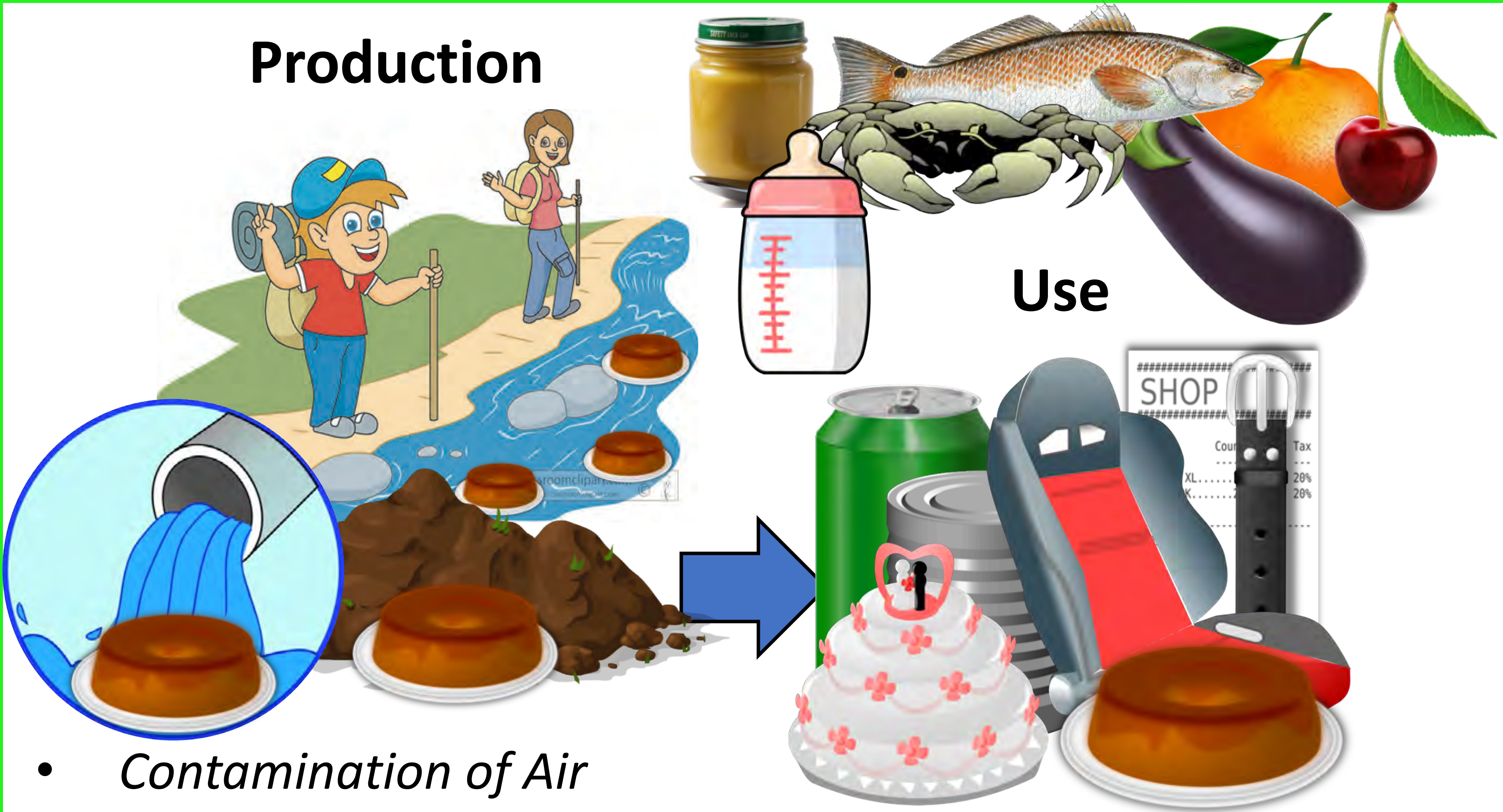


- *Contamination of Foods*
- *Contamination of Beverages*



- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*



- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

- When we touch receipts, BPA is transferred to the skin

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
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Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

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Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- When we touch receipts, BPA is transferred to the skin
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Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

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- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*
- *Shaving cream*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*
- *Shaving cream*
- *Lotions*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*
- *Shaving cream*
- *Lotions*
- *Shampoo*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*
- *Shaving cream*
- *Lotions*
- *Shampoo*
- *Bar soap*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*
- *Shaving cream*
- *Lotions*
- *Shampoo*
- *Bar soap*
- *Sunscreen*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
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Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

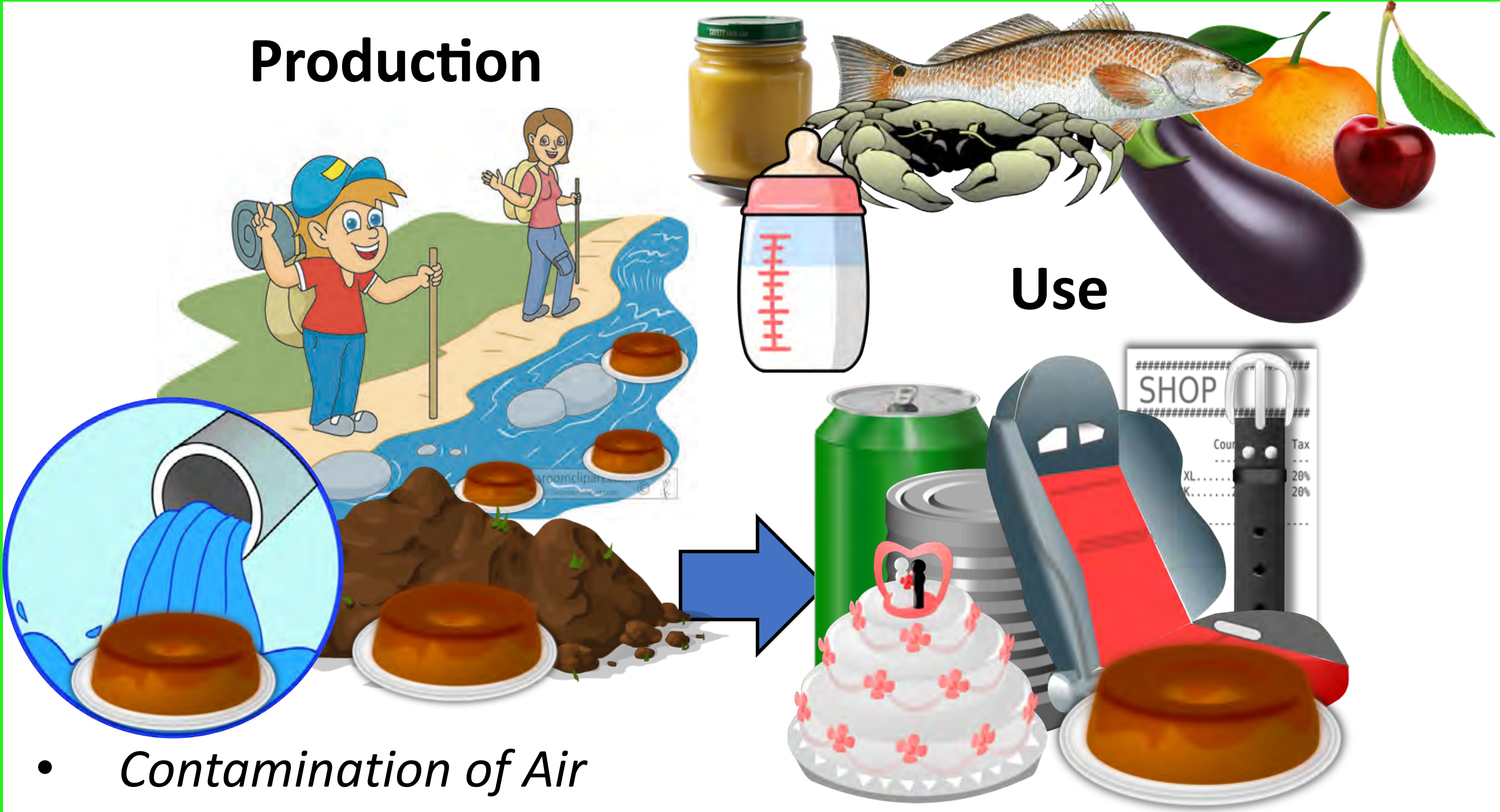
- *Cleansers*
- *Conditioner*
- *Shaving cream*
- *Lotions*
- *Shampoo*
- *Bar soap*
- *Sunscreen*
- *Toothpaste*

- When we touch receipts, BPA is transferred to the skin
- The amount transferred to the skin increases by a factor of 10 when skin is wet or greasy
- The BPA can then migrate into the skin
- Migration increases when a vector such as hand cream or lotion is present

Vandenberg 2013, Zalko 2011, Biedermann 2010, Dodson 2012

Contaminated Personal Care-Hygiene Products

- *Cleansers*
- *Conditioner*
- *Shaving cream*
- *Lotions*
- *Shampoo*
- *Bar soap*
- *Sunscreen*
- *Toothpaste*
- *Face and body wash*

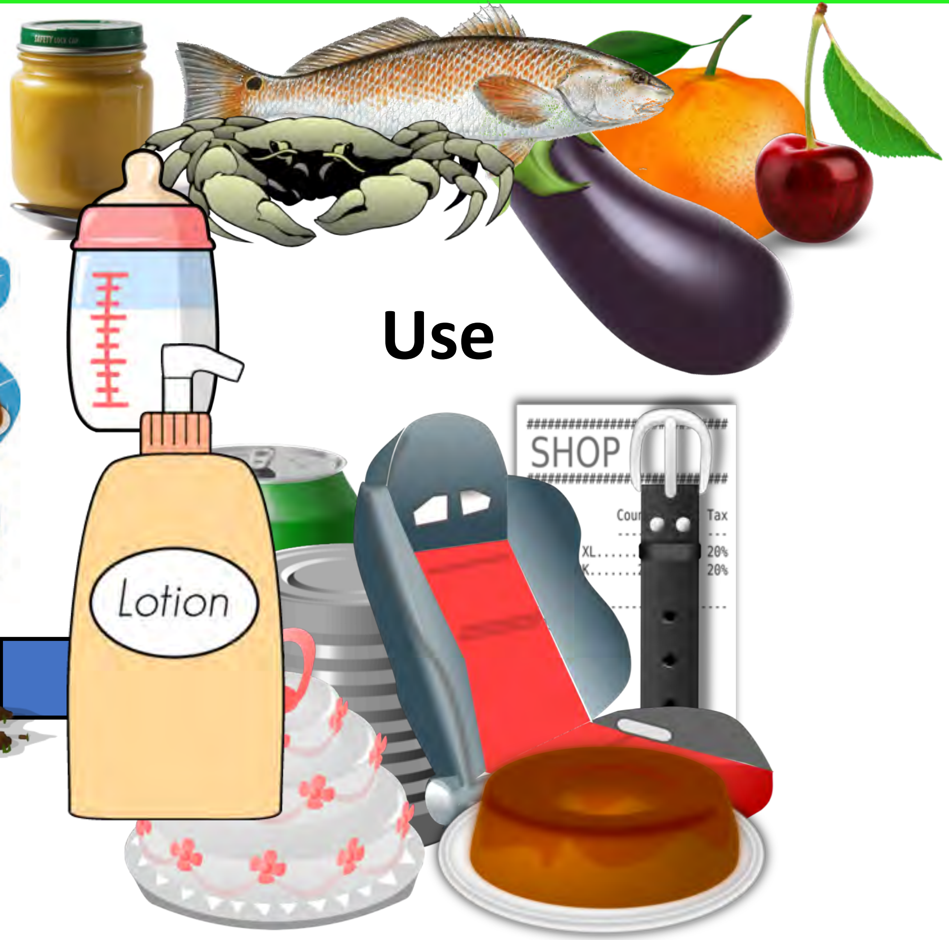


- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*

Production

Use



- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*

Production

Use

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

What Are the Concentrations of BPA in People?

Human Tissue and Fluid Concentrations of BPA and Total BPA. Refs: vom Saal 2007, NHANES 2003, Kuruto-Niwa 2007, Ye 2006

Fluid or Tissue	n	% Positive	Range ($\mu g\ L^{-1}$)	Central Tendency / Mean ($\mu g\ L^{-1}$)
Foetal, Child, and Adult Fluids and Tissues	—	—	—	Central Tendency: 0.3–4.4 $\mu g\ L^{-1}$ BPA
Urine of Americans Over 6 Years Old	2,517	92.6%	0.3–149 $\mu g\ L^{-1}$ Total BPA	Mean: 5.2 $\mu g\ L^{-1}$ Total BPA
Colostrum of Japanese Mothers	101	100%	1–7 $\mu g\ L^{-1}$ Total BPA	Mean: 3.41 $\mu g\ L^{-1}$ Total BPA
Breast Milk of American Mothers	20	90%	<0.3–6.3 $\mu g\ L^{-1}$ of BPA	Mean: 1.3 $\mu g\ L^{-1}$ BPA

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What Are Human Health Effects of These Exposures?

Richter 2004, Shelby 2008, Vandenberg 2013

A Panel from the National Institute for Environmental Health and Safety

Richter 2004, Shelby 2008, Vandenberg 2013

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- *“Confident” of human effects on the male reproductive tract arising from* ***adult exposures***

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US National Toxicology Program Panel and the US Food and Drug Administration

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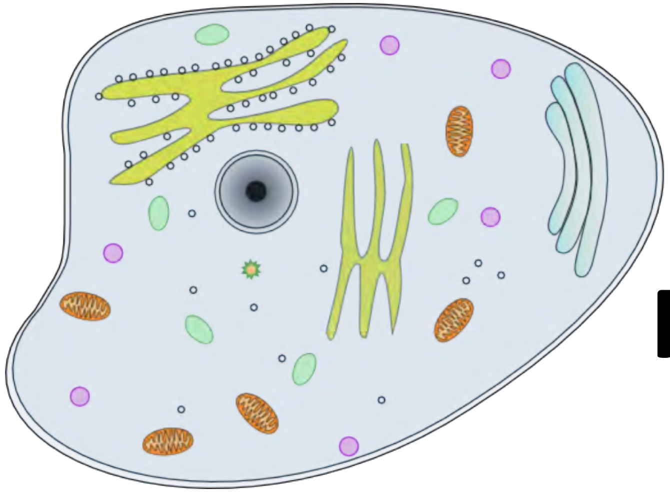
US National Toxicology Program Panel and the US Food and Drug Administration

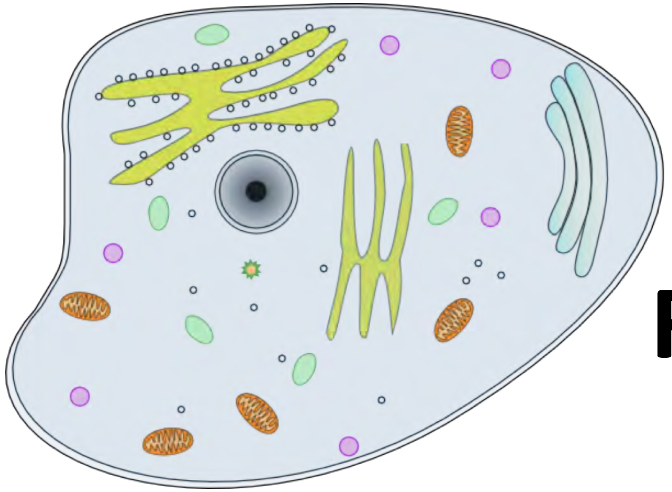
- *"Some concern" for effects on the brain, behavior, and male prostate gland arising from **foetus, infant, and child exposures***

Richter 2004, Shelby 2008, Vandenberg 2013

What Effects Have Been Reported To Arise From Exposures Of Human Cells To These BPA Concentrations?



Studies of Exposures of Human Cells to the Concentrations of BPA Observed in Foetal, Child, and Adult Fluids and Tissues Indicate That:



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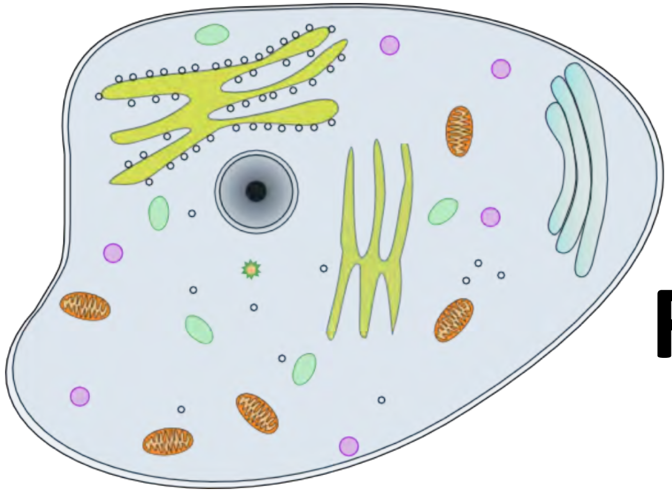
- *BPA can be as potent as estradiol, an endogenous hormone*

Prins 2014



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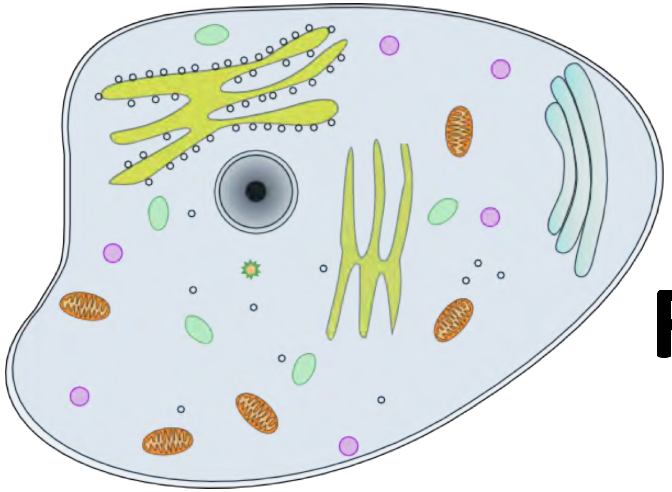

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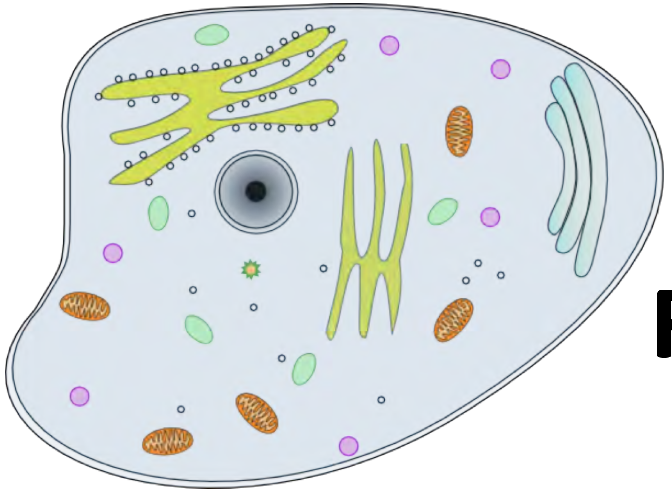

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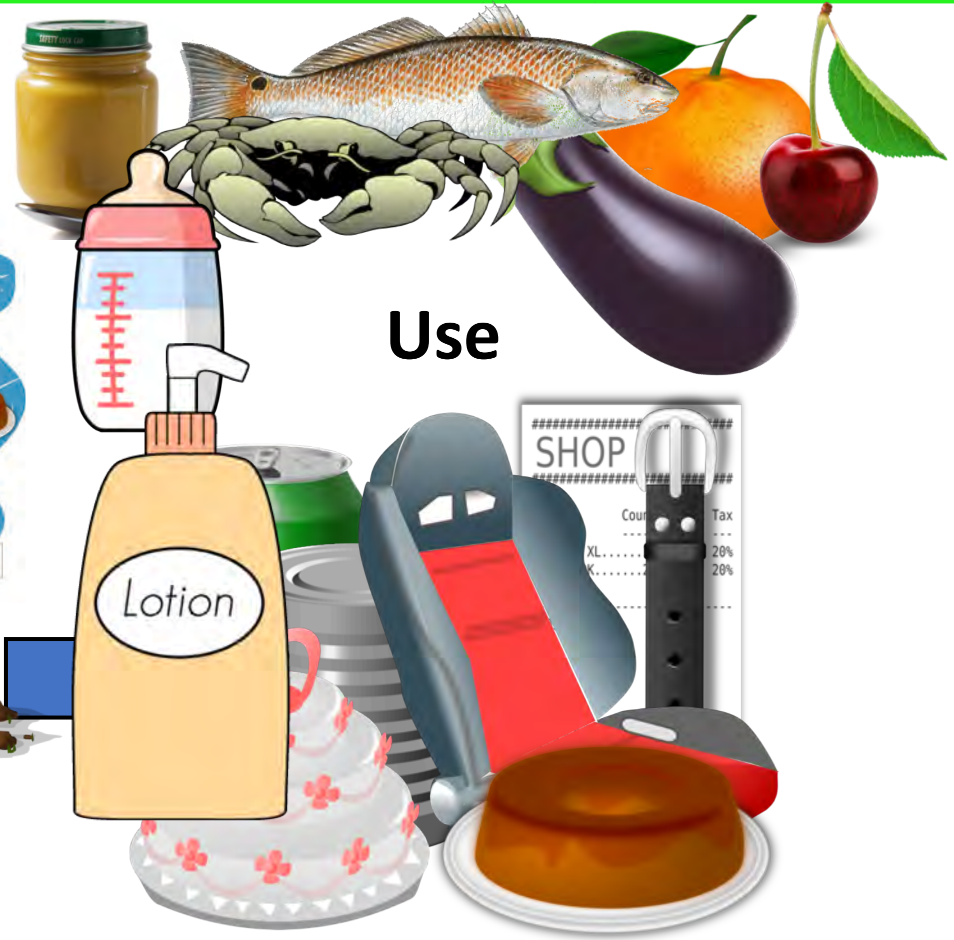
- *Exposure may adversely effect metabolic homeostasis*
  Ben-Jonathan 2009, Hugo 2008

Production

Use



- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

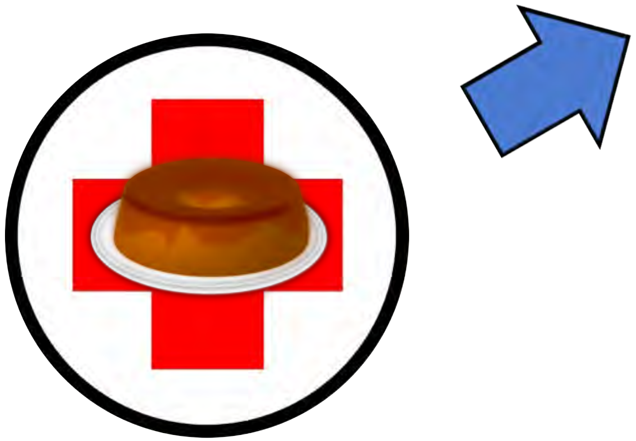
Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use



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Production

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- *Contamination of Water*
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Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Disposal

What Is the Fate of BPA Containing Goods?

In the US in 2014, 258 million tons of municipal solid waste were generated.

Fates of the 258 million tons of municipal solid waste generated in the US in 2014. Ref: USEPA 2014

Waste	Million tons (mt)	Percent Landfilled	Percent Recycled	Percent Combusted
Paper and Paperboard	69	28	65	7
Plastics	33	76	10	15
Textiles	16	65	16	19
Rubber and Leather	8	51	18	32

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- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Disposal

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Disposal

- *Contamination of Air*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
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Disposal

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Polycarbonate

60% of the produced BPA

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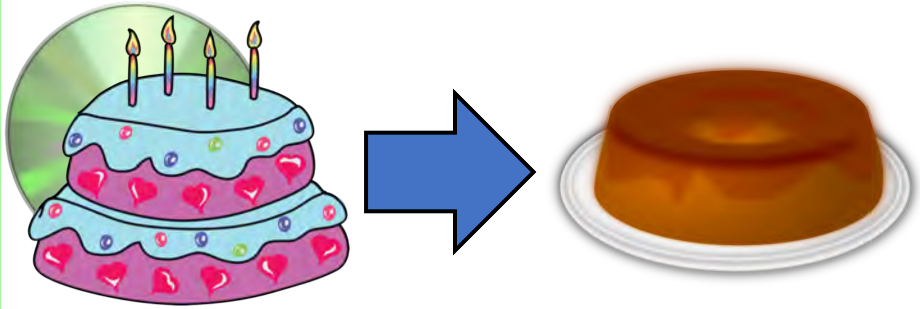

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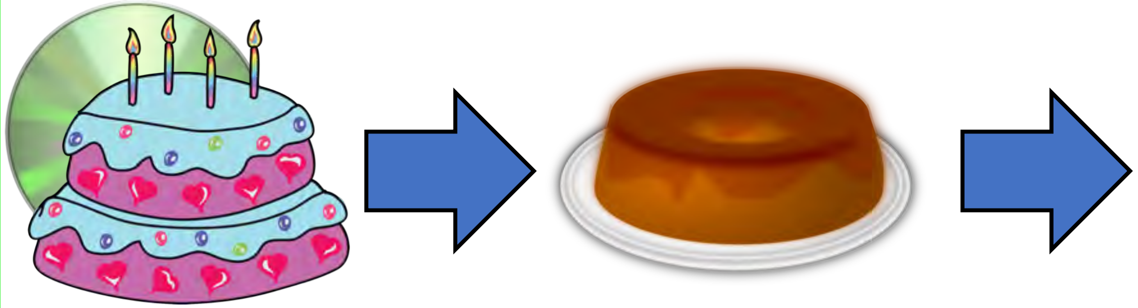

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Concentrations of BPA Detected in Landfill Leachate

Country	Year	Range ($\mu g\ L^{-1}$)	Average ($\mu g\ L^{-1}$)	Ref.
Germany	2002	4,200–25,000	14,067	Schwarzbauer
Germany	2003	500–5,000	—	Wintgens
Japan	1999	*ca.* 500–7,500	—	Yamada
Japan	1996	<0.5–17,200	269	Yamamoto
Norway	2015	0.7–200	66.5	Morin
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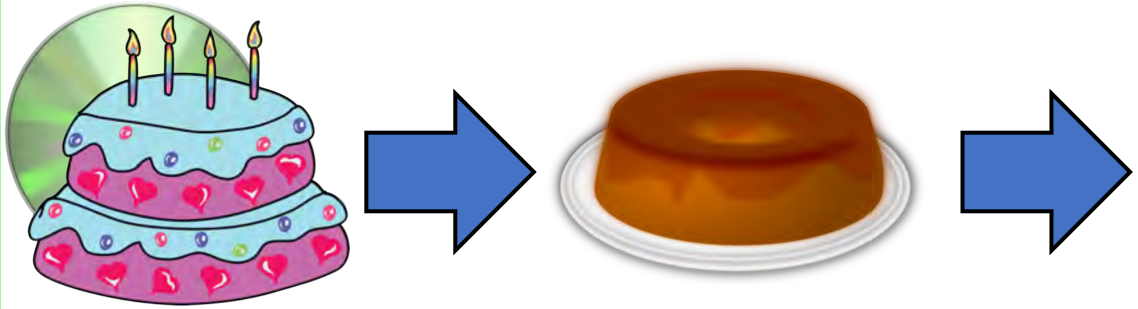
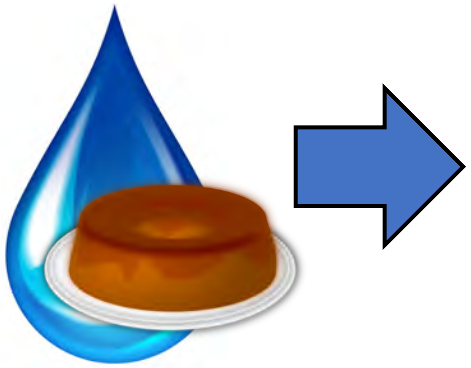

Polycarbonate

95% of the produced BPA

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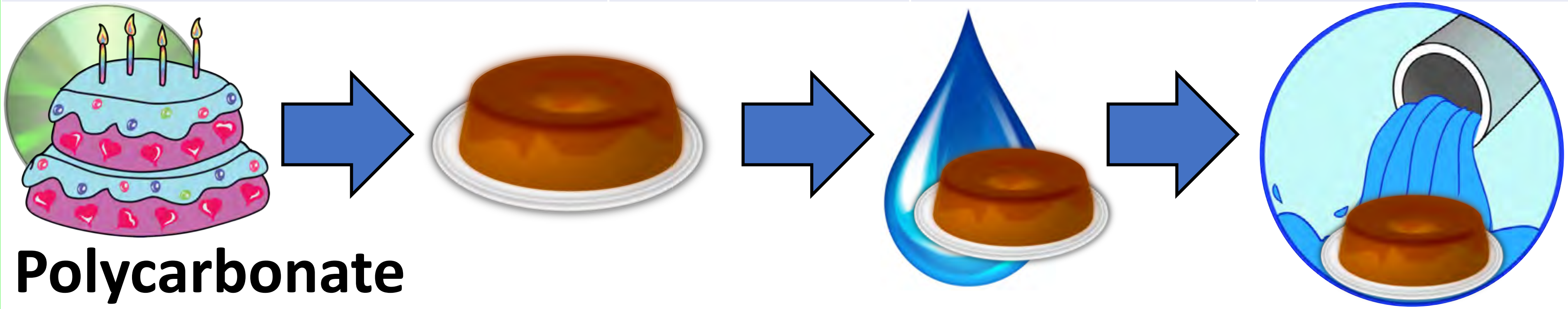

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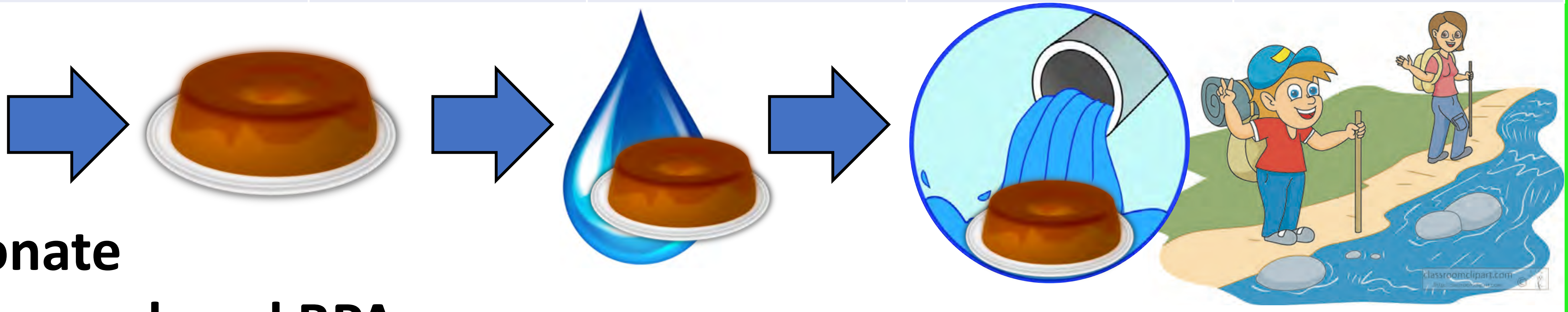

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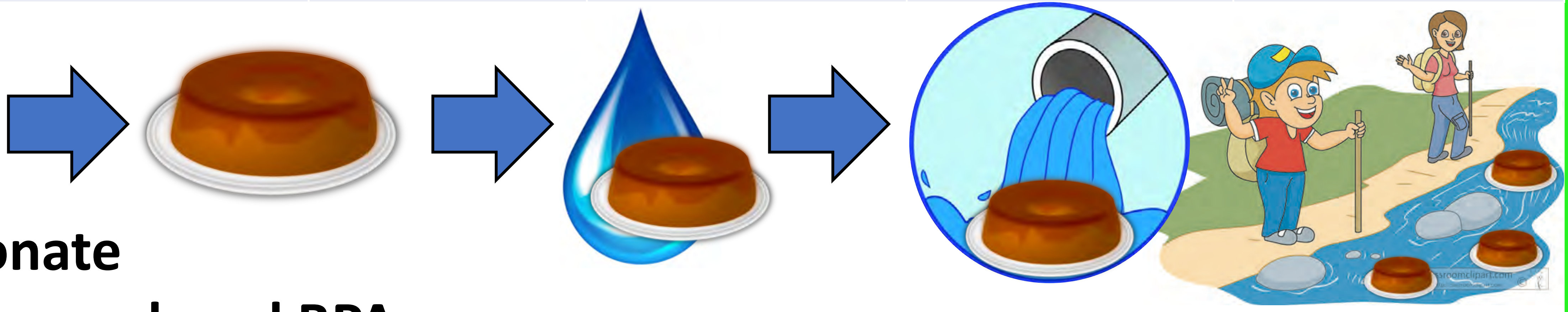

Polycarbonate

95% of the produced BPA

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Disposal

- *Contamination of Air*
- *Contamination of Water*

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

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Disposal

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Production

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Use

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Disposal

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- *Contamination of Water*
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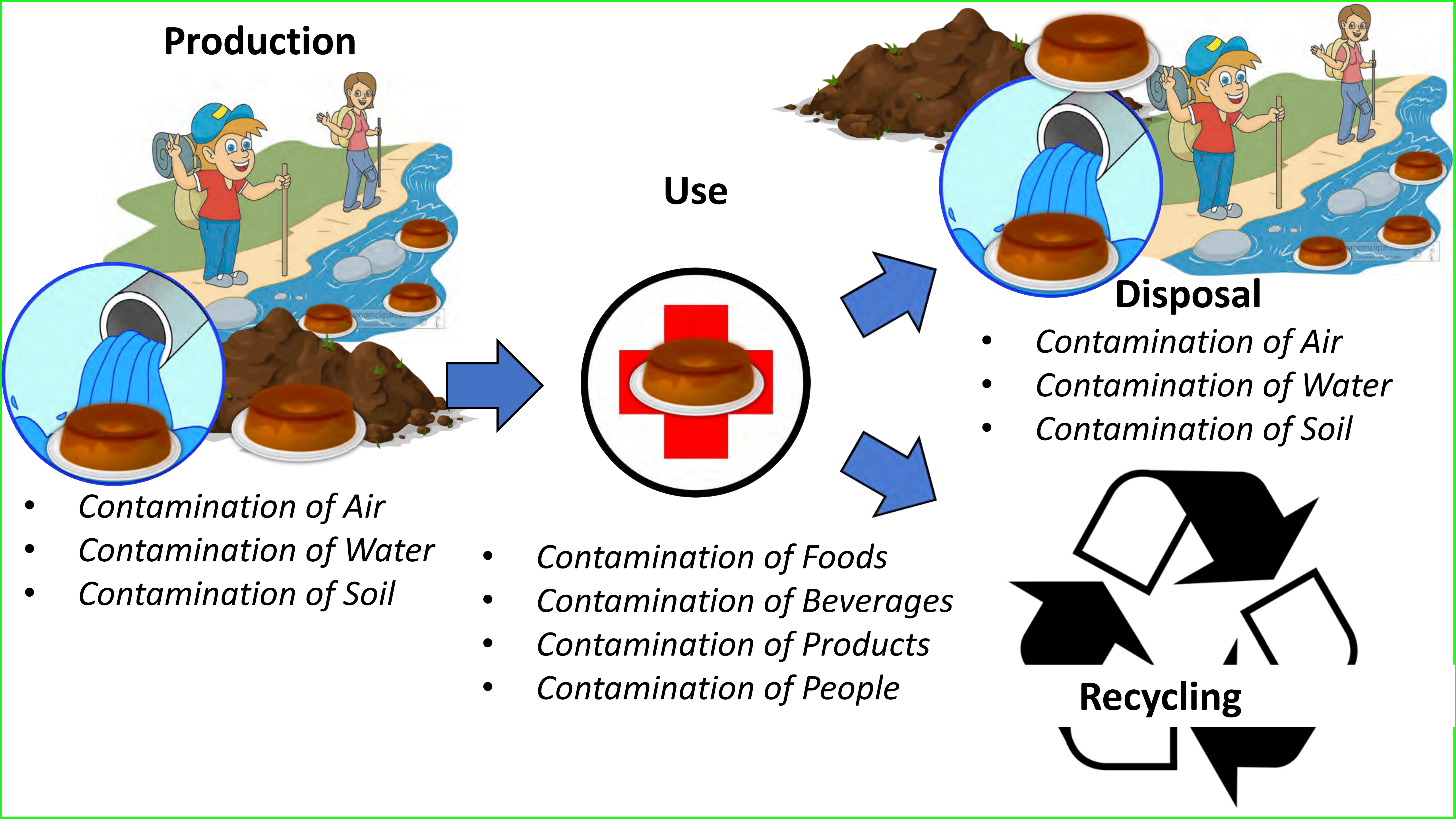
Production
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Contamination of Water
Contamination of Soil
Use
Contamination of Foods
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Contamination of People
Disposal
Contamination of Air
Contamination of Water
Contamination of Soil
Recycling

Production

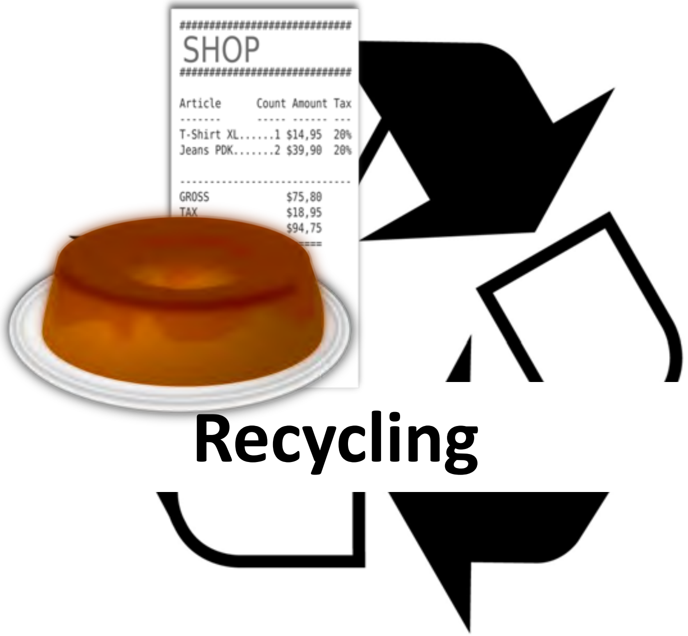
- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Disposal

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*



Recycling

Production

- Contamination of Air
- Contamination of Water
- Contamination of Soil

Use

- Contamination of Foods
- Contamination of Beverages
- Contamination of Products
- Contamination of People

Disposal

- Contamination of Air
- Contamination of Water
- Contamination of Soil

Recycling

- Contamination of Recycled Cellulose Fiber

Production

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Use

- *Contamination of Foods*
- *Contamination of Beverages*
- *Contamination of Products*
- *Contamination of People*

Disposal

- *Contamination of Air*
- *Contamination of Water*
- *Contamination of Soil*

Recycling

- *Contamination of Recycled Cellulose Fiber*
- *Contamination of Air, Water, and Soil*

Worldwide Contamination of Recycled Cellulose Fiber (RCF)

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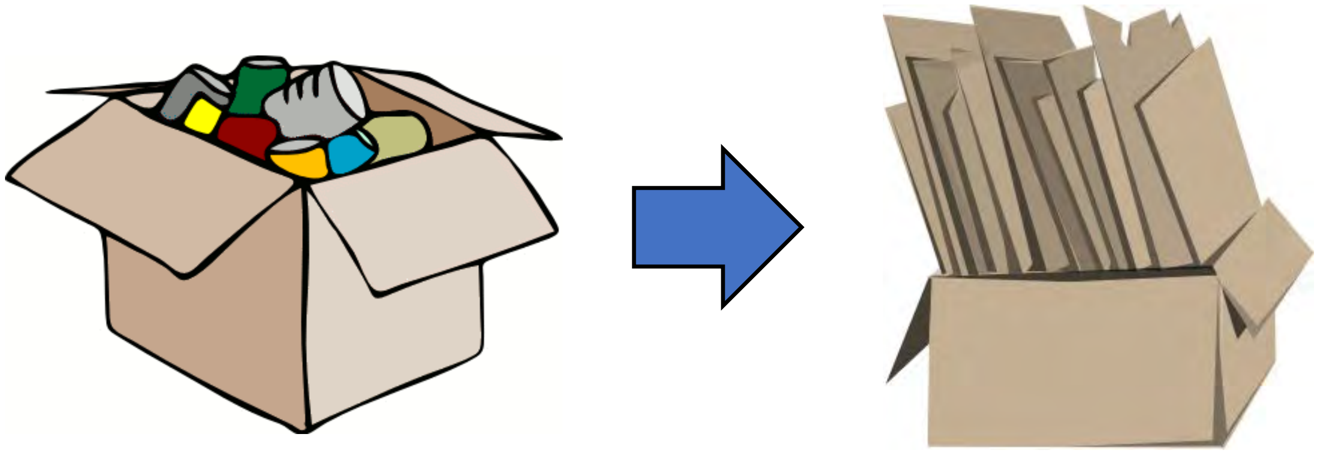
Worldwide Contamination of Recycled Cellulose Fiber (RCF)



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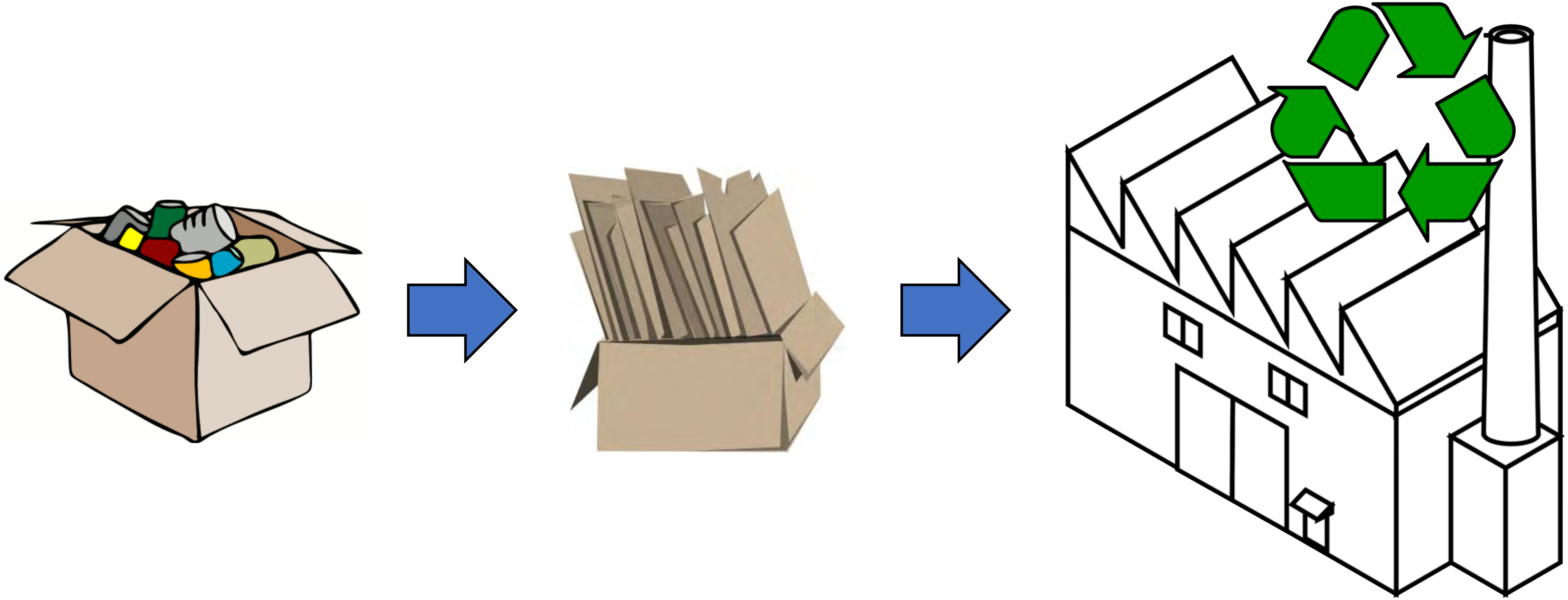

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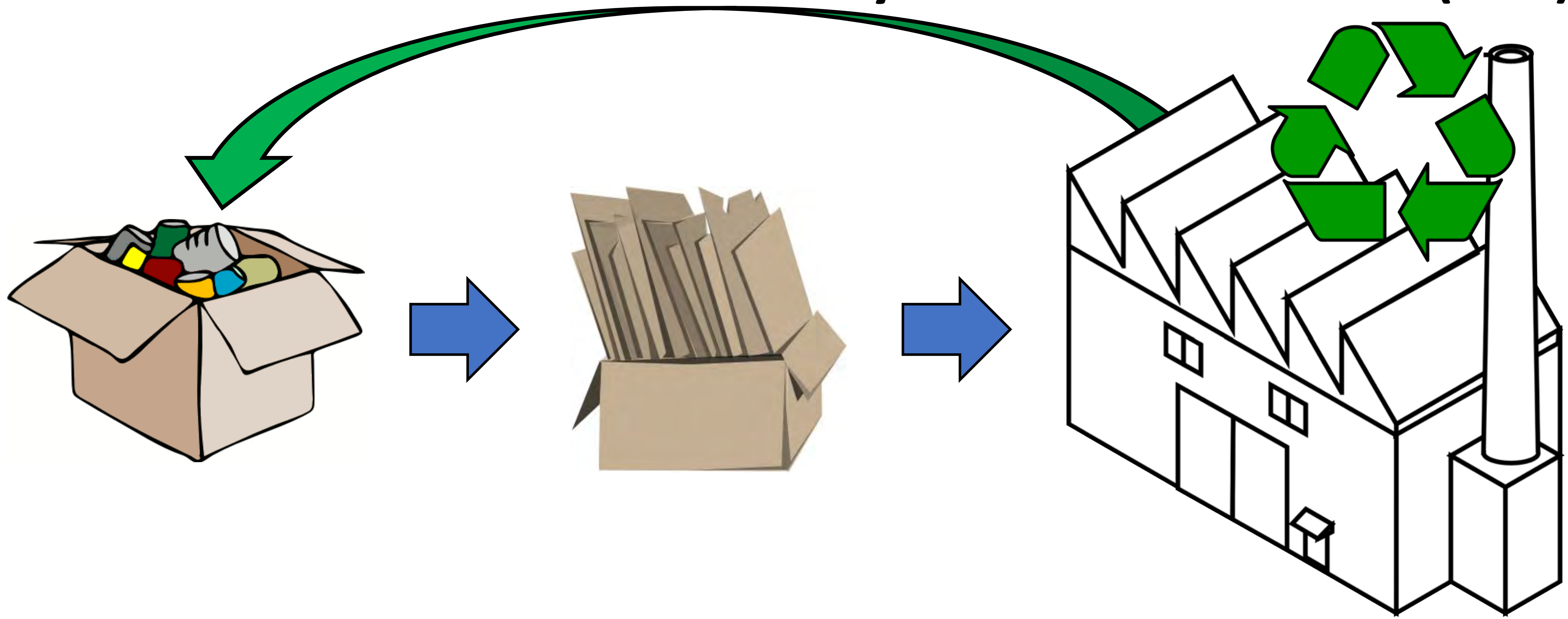

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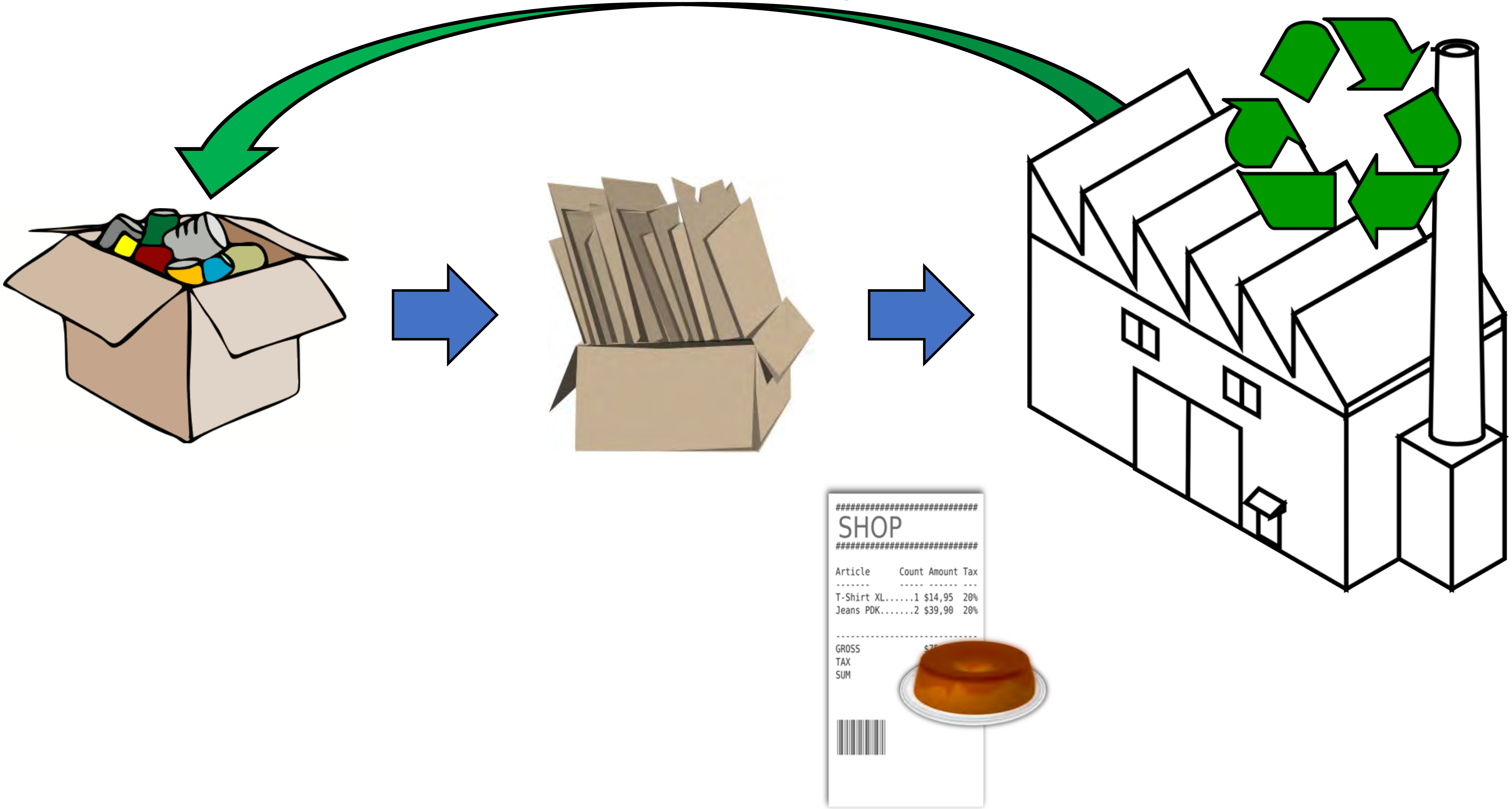

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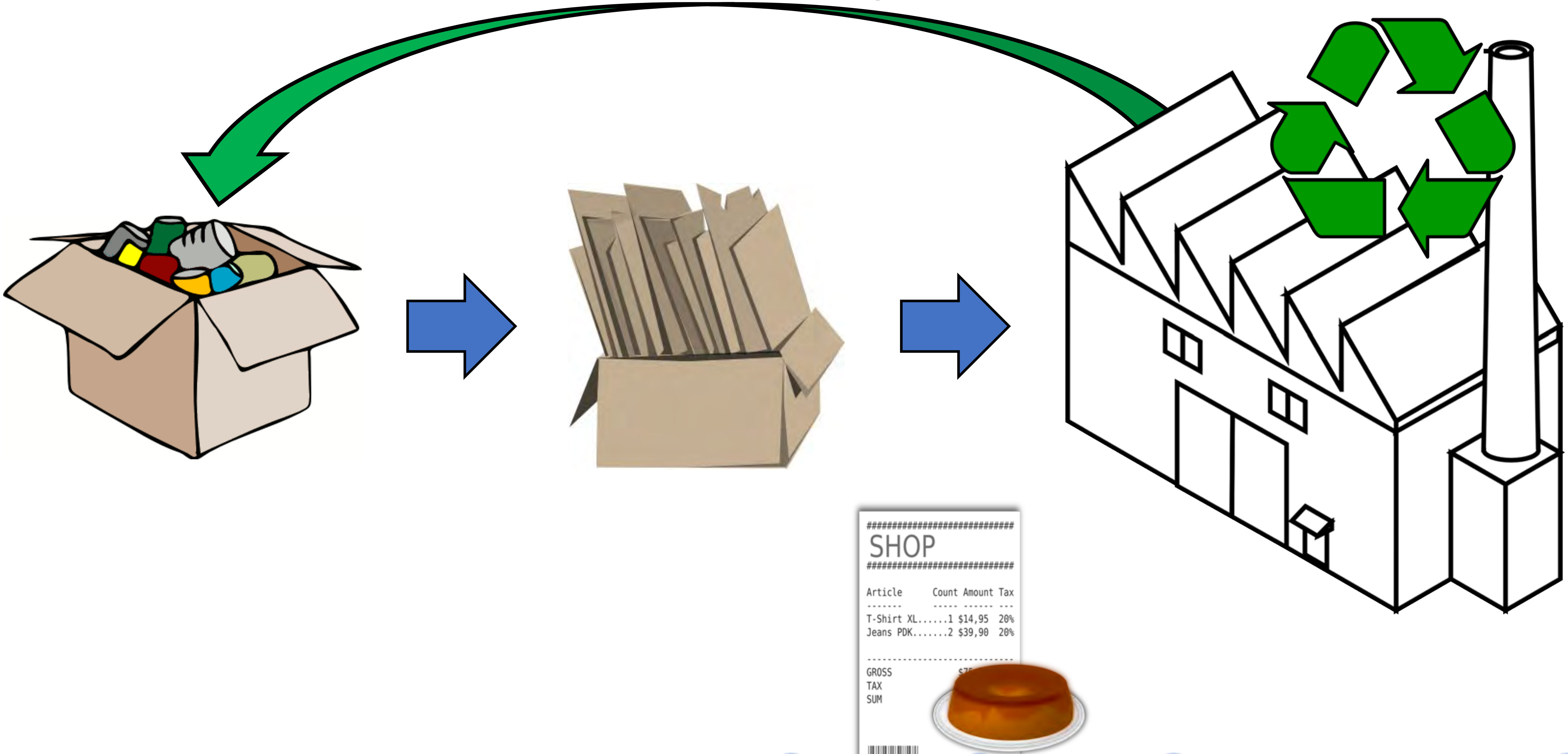

EU 2008 **Ca. 10% produced, and 30% used**

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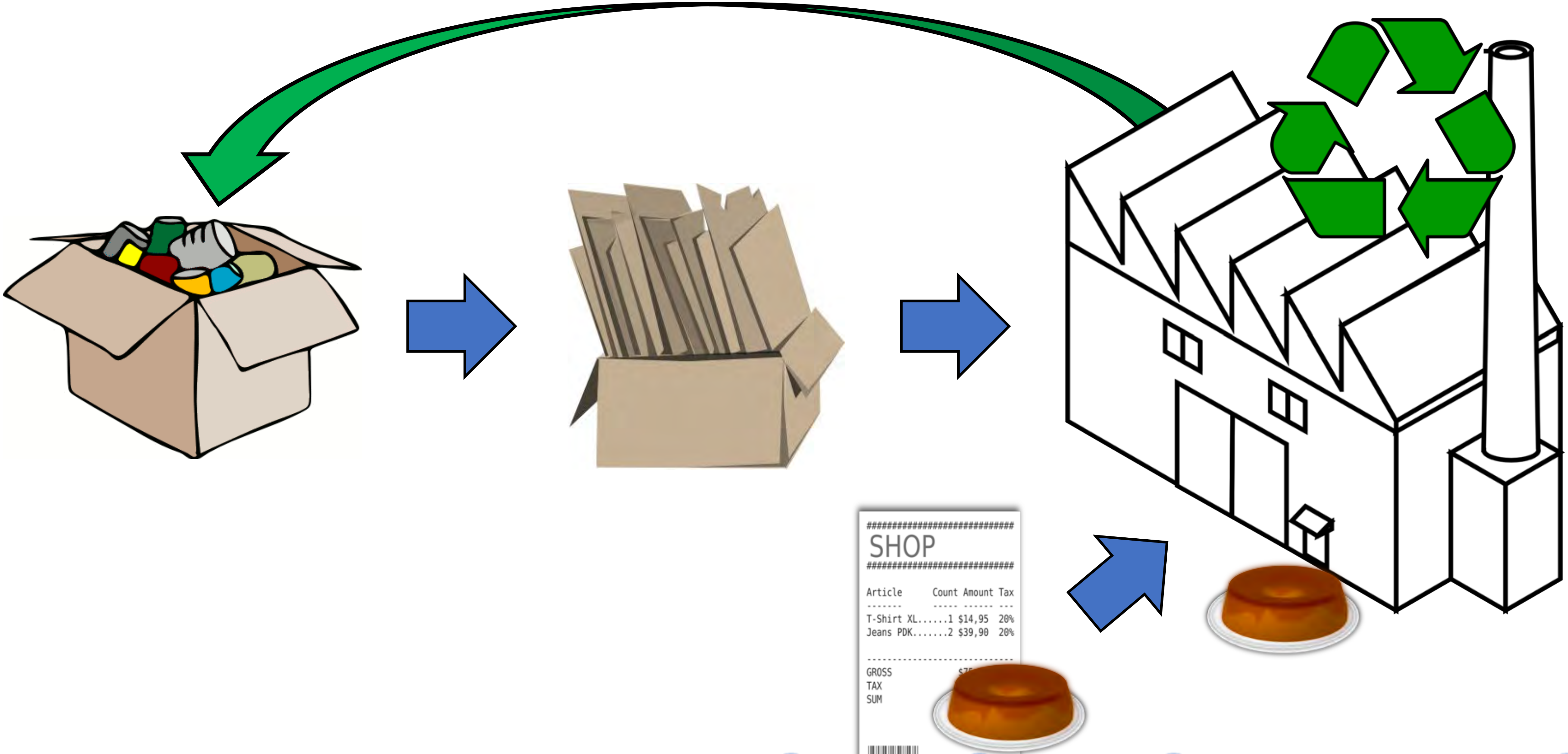

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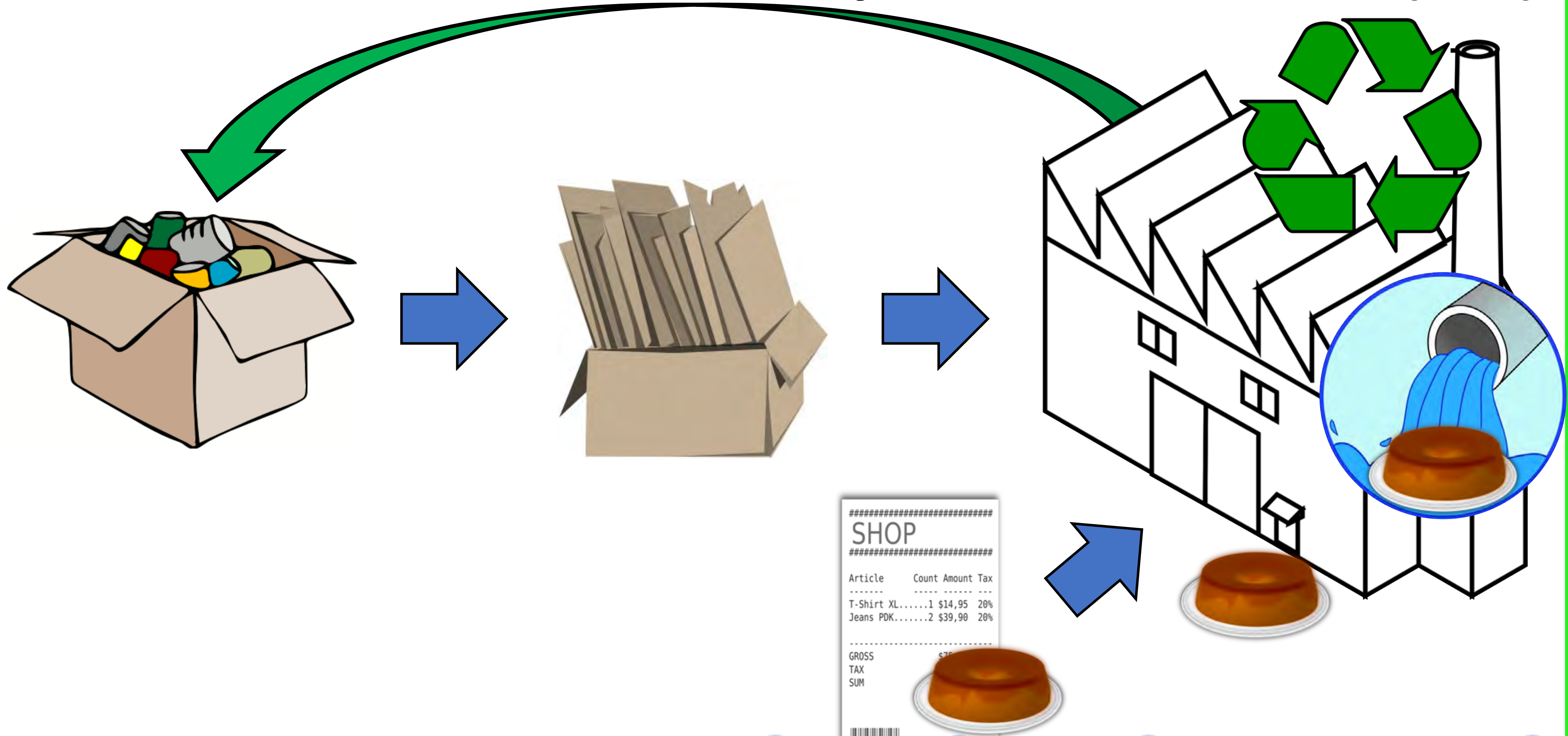

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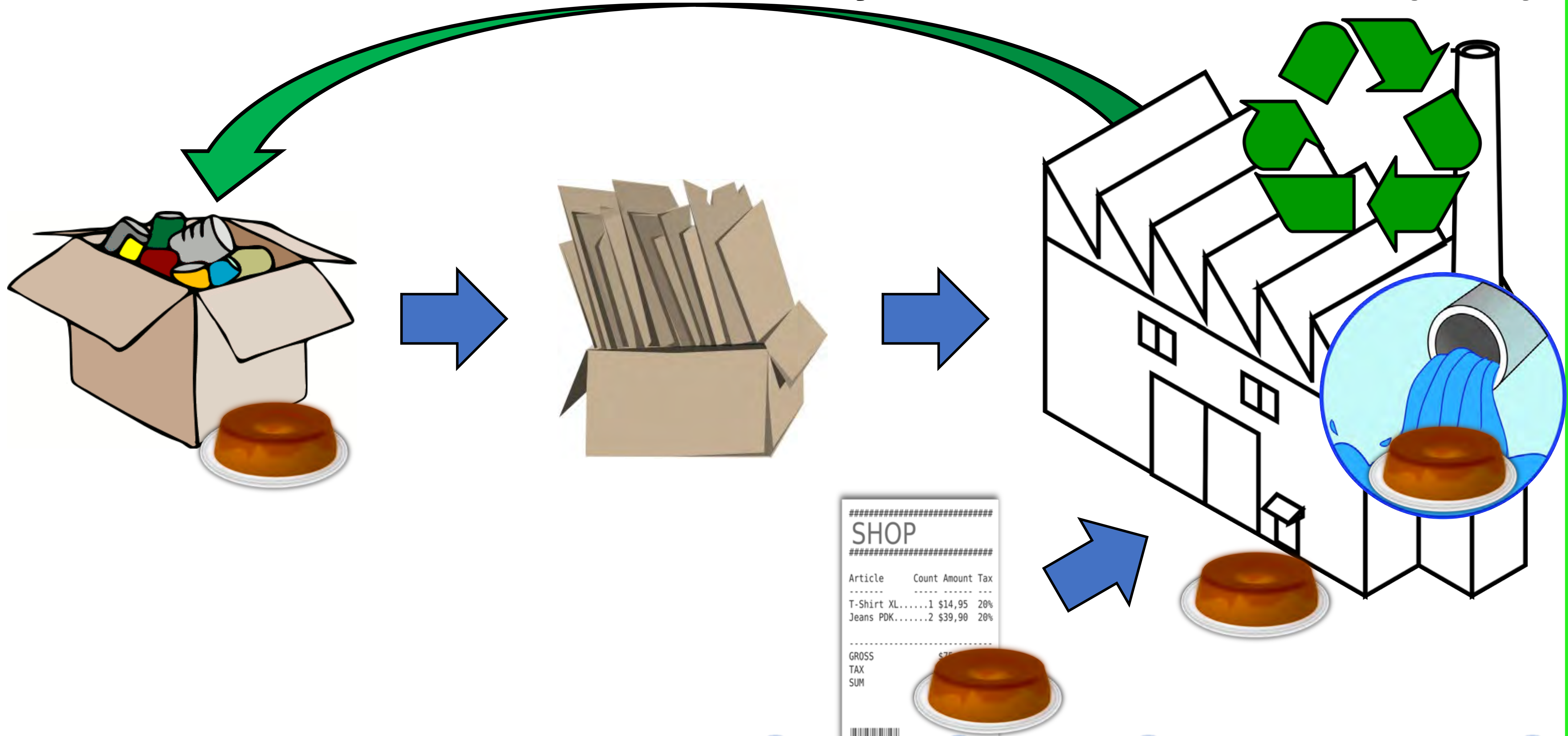

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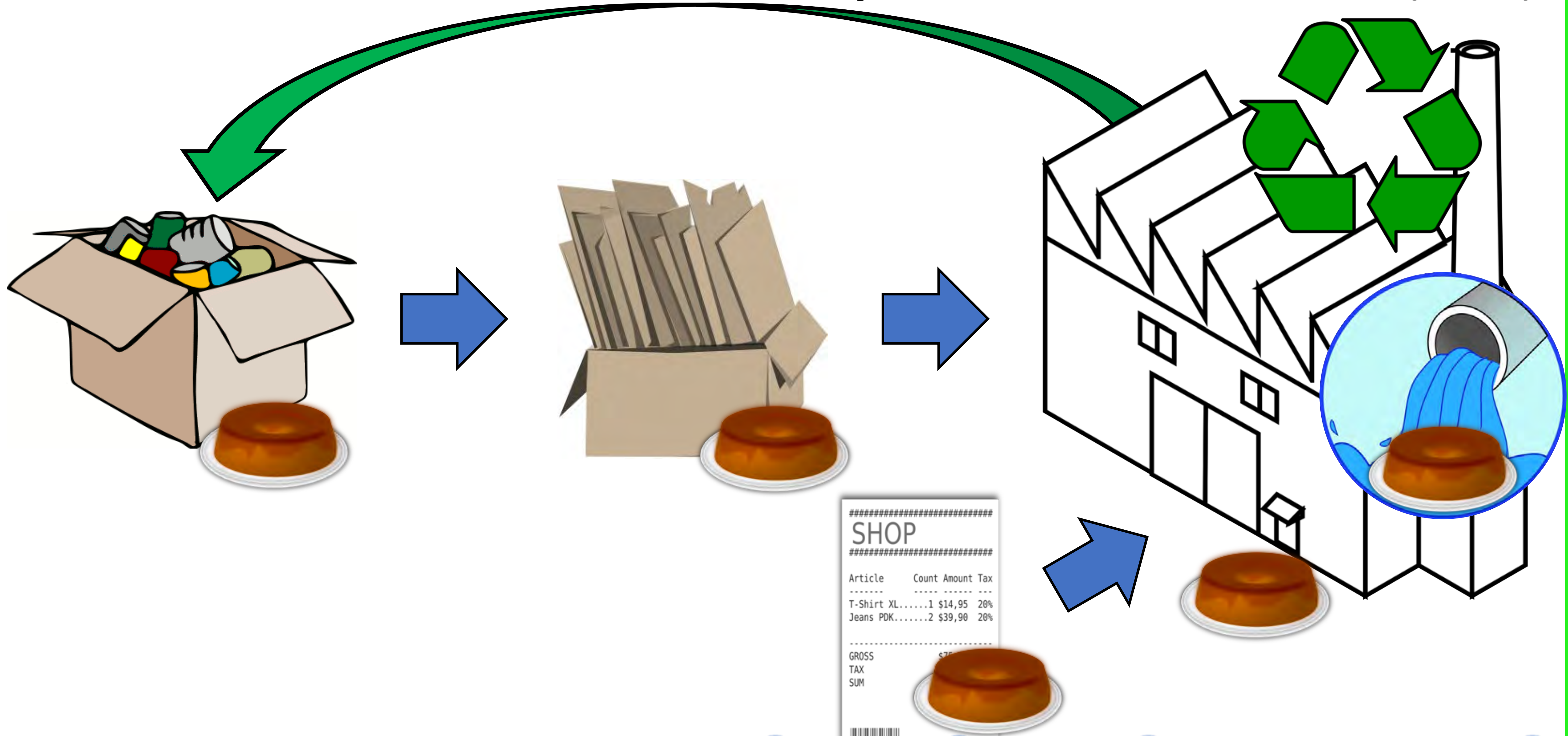

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Worldwide Contamination of Recycled Cellulose Fiber (RCF)

Ca. 50% of the furnish for worldwide paper and board production is likely contaminated

Liao 2011, Gehring 2014, Nordstrom 2013

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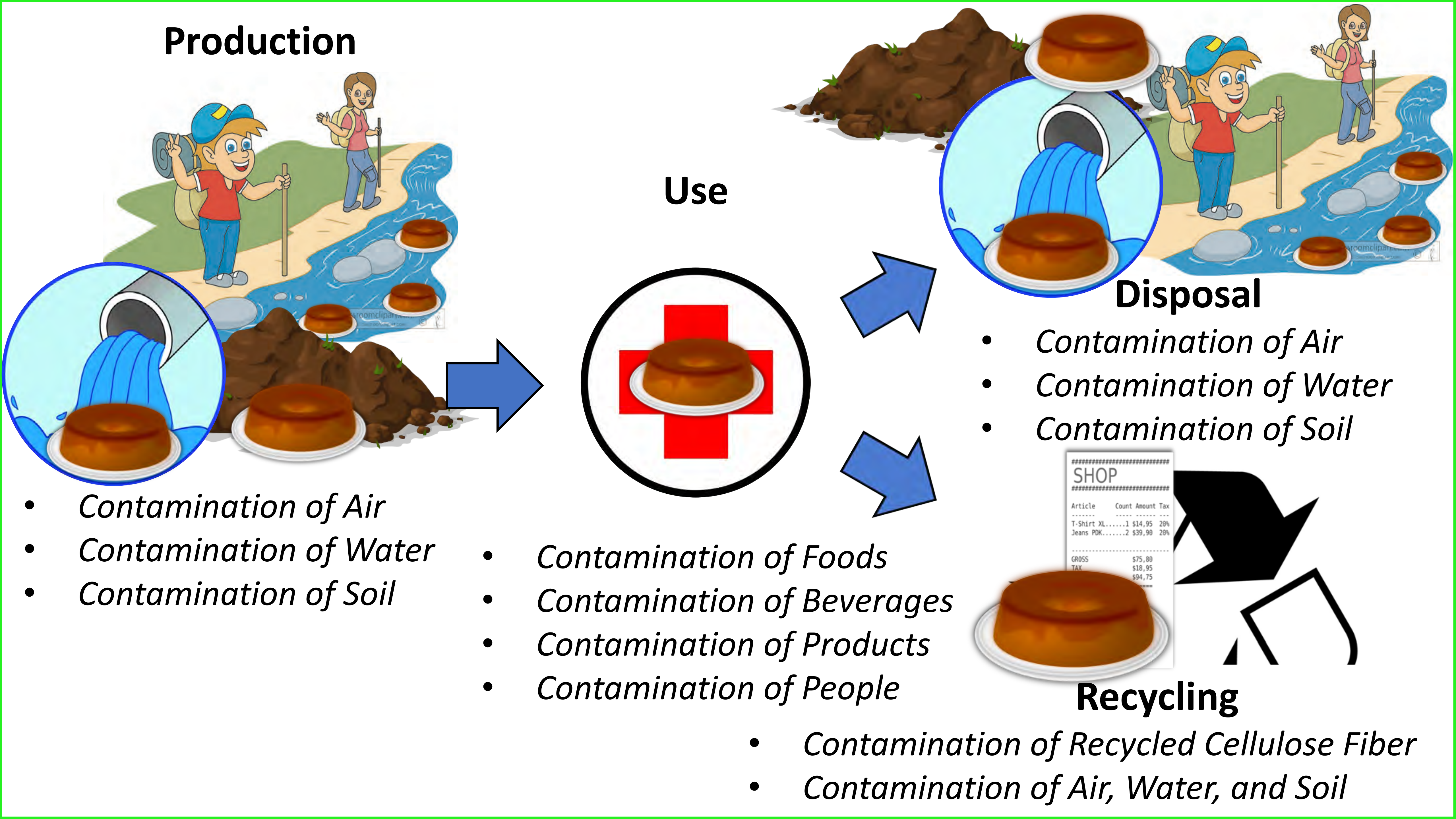
Production
Contamination of Air
Contamination of Water
Contamination of Soil
Use
Contamination of Foods
Contamination of Beverages
Contamination of Products
Contamination of People
Disposal
Contamination of Air
Contamination of Water
Contamination of Soil
SHOP
Article Count Amount Tax
T-Shirt XL......1 $14,95 20%
Jeans PDK.......2 $39,90 20%
GROSS $75,80
TAX $18,95
$94,75
Recycling
Contamination of Recycled Cellulose Fiber
Contamination of Air, Water, and Soil

Production

- Contamination of Air
- Contamination of Water
- Contamination of Soil

Use

- Contamination of Foods
- Contamination of Beverages
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Recycling

- Contamination of Recycled Cellulose Fiber
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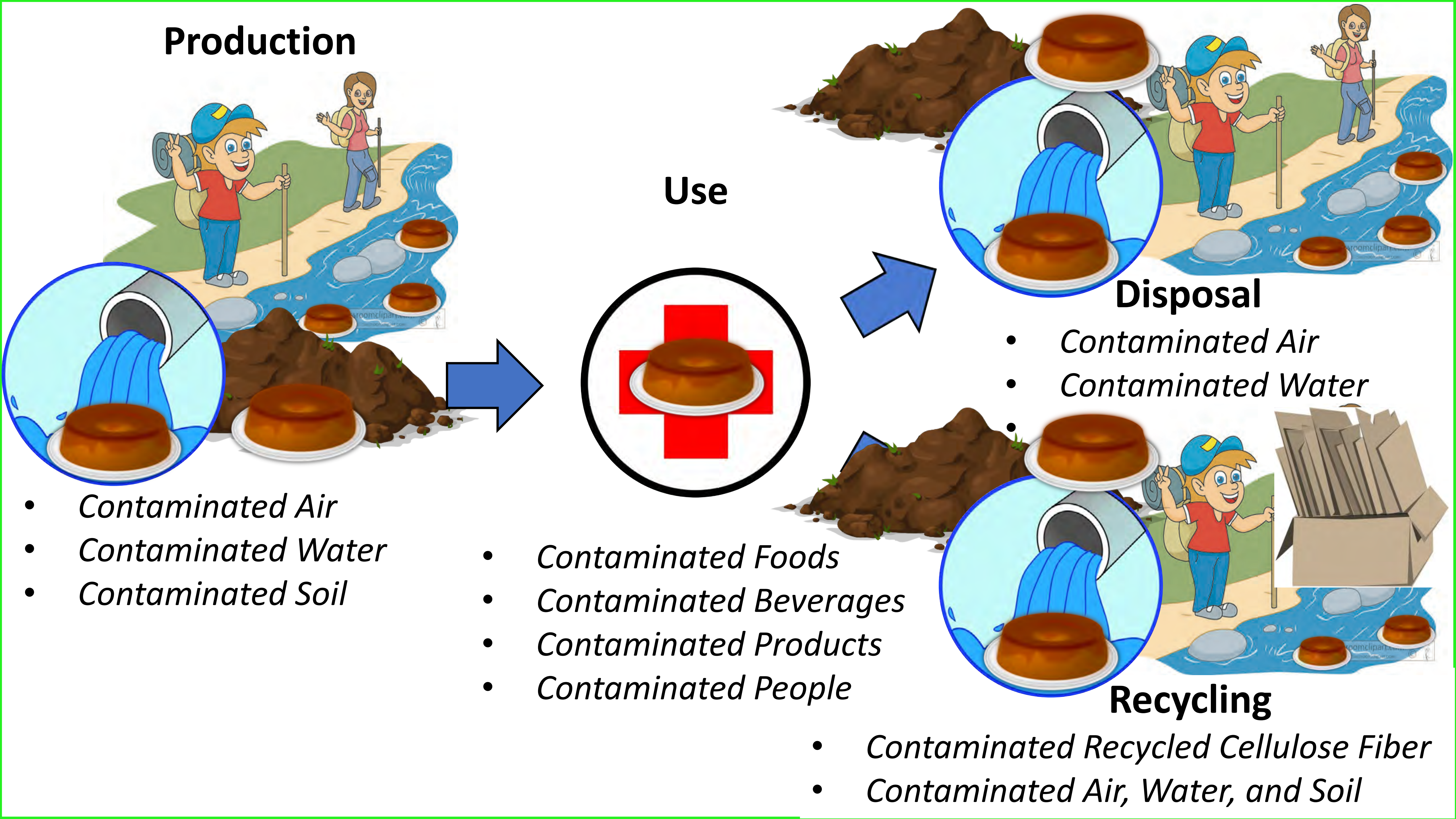
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Use

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- *Contaminated People*

Disposal

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- *Contaminated Water*

Recycling

- *Contaminated Recycled Cellulose Fiber*
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Disposal

- *Contaminated Air*
- *Contaminated Water*
-

Recycling

- *Contaminated Recycled Cellulose Fiber*
- *Contaminated Air, Water, and Soil*

- *Remove BPA from landfill leachate*

- *Remove BPA from landfill leachate and WWTP influent*

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GREEN
SCIENCE
CARNEGIE MELLON UNIVERSITY

CARNEGIE MELLON UNIVERSITY
PITTSBURGH PENNSYLVANIA 1900

We have developed treatment processes that …

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- *Convert >99% of BPA in near-neutral pH lab water, a simulant of landfill leachate and WWTP influent, to an insoluble form*

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- *Convert >99.9 of BPA in pH ≥11 lab water, a simulant of RCF processing solutions, to CO, CO_2, acetone, and trace formate*

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Acknowledgements

Phipps Conservatory

Richard Piacentini

Sarah States

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Colin P. Horwitz

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Ryan T. Malecky

Bethany A. Drake

University of Auckland

Naresh Singhal

L. James Wright

Yusuf Onundi

Oregon State University

Robert L. Tanguay

Lisa Truong

Michael T. Simonich

Thank You All For Your Attention!

Bisphenol A First Synthesized in Germany

Thomas Zincke of the University of Marburg, Germany, first reported synthesis of bisphenol A. Zincke acknowledged in his paper that the synthesis of BPA, from phenol and acetone, was based on chemical reactions previously reported by others as well as unpublished work (from thesis dissertations) conducted at the University of Marburg. His paper reporting the synthesis of BPA and a number of related compounds was published in 1905. (Zincke, T., 1905, "Mittheilungen aus dem chemischen Laboratorium der Universitat Marburg," Justus Leibigs Annals Chemie, vol. 343, pages 75-99).

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$$\begin{matrix}CH_3\\CH_3\end{matrix}\!\!>CO + 2C_6H_5.OH = \begin{matrix}CH_3\\CH_3\end{matrix}\!\!>C<\!\!\begin{matrix}C_6H_4.OH\\C_6H_4.OH\end{matrix} + H_2O,$$

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Synthetic Œstrogenic Agents without the Phenanthrene Nucleus

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1 : 2-Dihydroxy-1 : 2-di-α-naphthyl-acenaphthene	100	100*
,, ,, ,,	10	100
1 : 1-Di-α-naphthyl acenaphthenone	100	100
α-Naphthyl benzoin	100	40
Diphenyl-α-naphthyl glycol	100	60
Diphenyl-α-naphthyl carbinol	100	100
4-4-Dihydroxydiphenyl methane	100	100
Di-(p-Hydroxyphenyl) dimethyl methane	100	100
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Di-(p-Hydroxyphenyl) methyl propyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl) di methyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl)-1 : 1-cyclo-hexane	100	100
2 : 4-Dihydroxy-triphenyl methane carboxylic acid lactone	100	100
4 : 4^1-Dihydroxy benzophenone	100	60
4 : 4^1-Dihydroxy diphenyl	100	100

* Rats remained in œstrus 40 days.

996

1936

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Diphenyl-α-naphthyl glycol	100	60
Diphenyl-α-naphthyl carbinol	100	100
4-4-Dihydroxydiphenyl methane	100	100
Di-(p-Hydroxyphenyl) dimethyl methane	100	100
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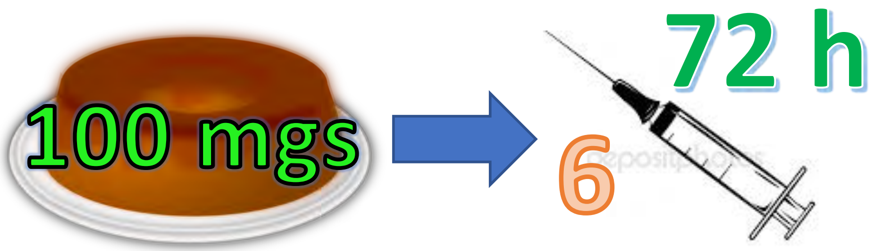

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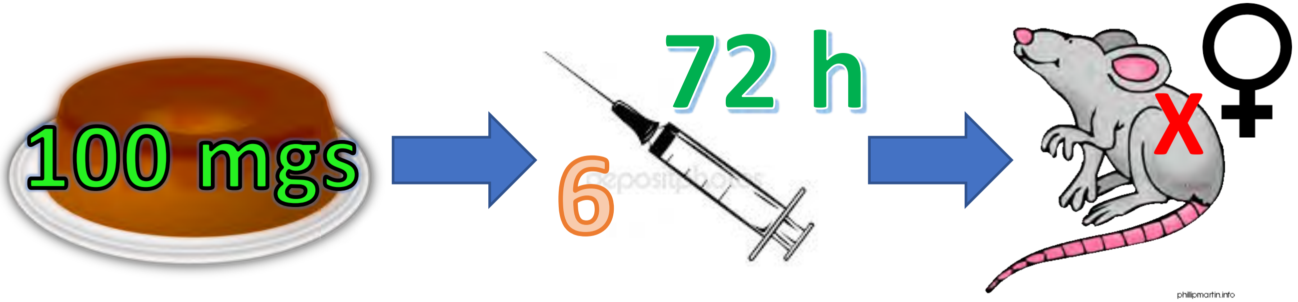

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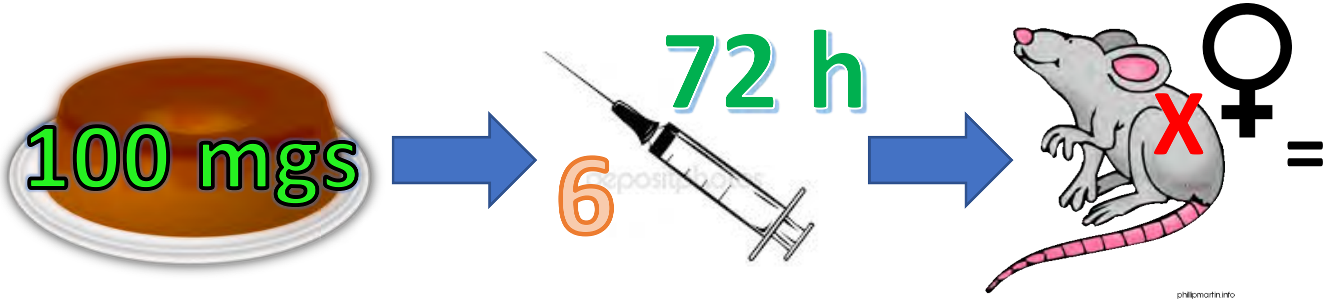

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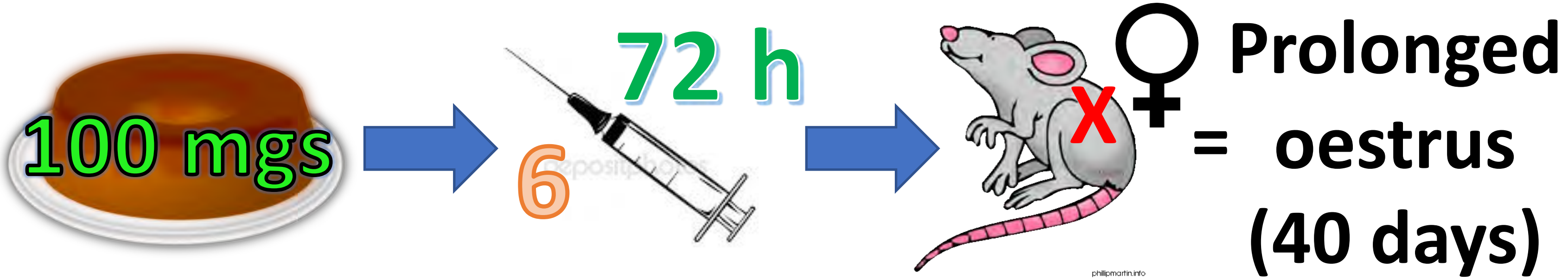
,, ,, ,,	10	100
1 : 1-Di-α-naphthyl acenaphthenone	100	100
α-Naphthyl benzoin	100	40
Diphenyl-α-naphthyl glycol	100	60
Diphenyl-α-naphthyl carbinol	100	100
4-4-Dihydroxydiphenyl methane	100	100
Di-(p-Hydroxyphenyl) dimethyl methane	100	100
Di-(p-Hydroxyphenyl) methyl ethyl methane	100	100
Di-(p-Hydroxyphenyl) methyl propyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl) di methyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl)-1 : 1-cyclo-hexane	100	100
2 : 4-Dihydroxy-triphenyl methane carboxylic acid lactone	100	100
4 : 4[1]-Dihydroxy benzophenone	100	60
4 : 4[1]-Dihydroxy diphenyl	100	100

* Rats remained in œstrus 40 days.



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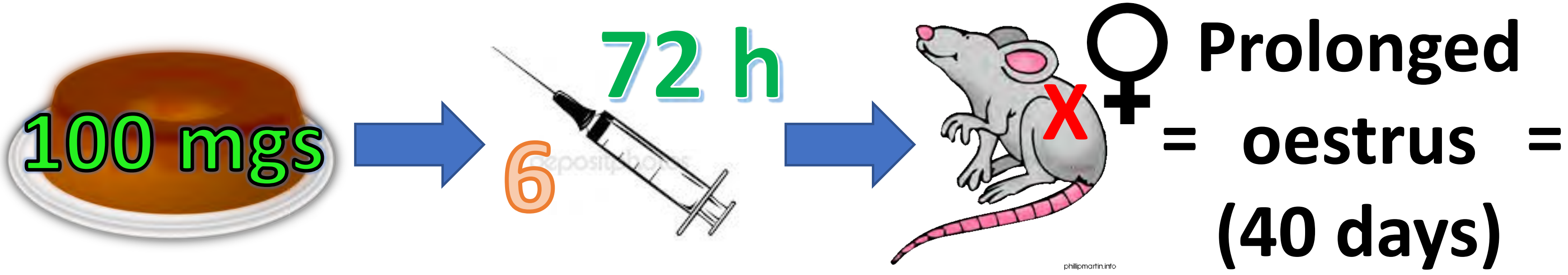
1936

Substance	Dose in mgm.	Percentage positive
1 : 2-Dihydroxy-1 : 2-di-α-naphthyl-acenaphthene	100	100*
,, ,, ,,	10	100
1 : 1-Di-α-naphthyl acenaphthenone	100	100
α-Naphthyl benzoin	100	40
Diphenyl-α-naphthyl glycol	100	60
Diphenyl-α-naphthyl carbinol	100	100
4-4-Dihydroxydiphenyl methane	100	100
Di-(p-Hydroxyphenyl) dimethyl methane	100	100
Di-(p-Hydroxyphenyl) methyl ethyl methane	100	100
Di-(p-Hydroxyphenyl) methyl propyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl) di methyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl)-1 : 1-cyclo-hexane	100	100
2 : 4-Dihydroxy-triphenyl methane carboxylic acid lactone	100	100
4 : 4[1]-Dihydroxy benzophenone	100	60
4 : 4[1]-Dihydroxy diphenyl	100	100

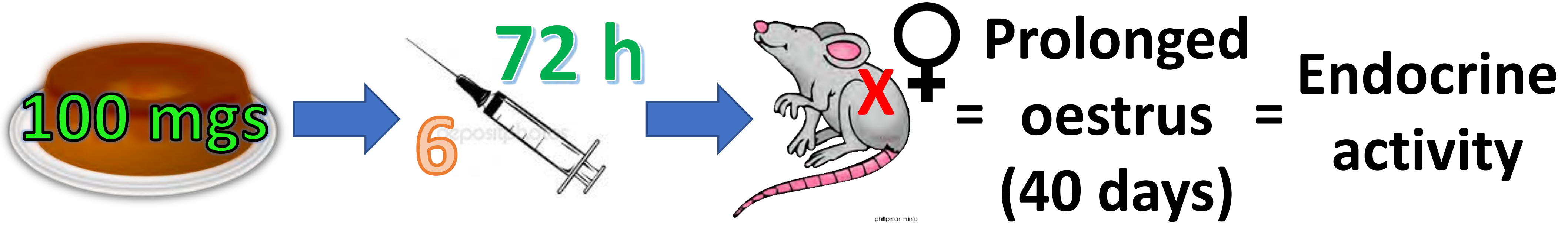
* Rats remained in œstrus 40 days.



996 1936

Substance	Dose in mgm.	Percentage positive
1 : 2-Dihydroxy-1 : 2-di-α-naphthyl-acenaphthene	100	100*
,, ,, ,,	10	100
1 : 1-Di-α-naphthyl acenaphthenone	100	100
α-Naphthyl benzoin	100	40
Diphenyl-α-naphthyl glycol	100	60
Diphenyl-α-naphthyl carbinol	100	100
4-4-Dihydroxydiphenyl methane	100	100
Di-(p-Hydroxyphenyl) dimethyl methane	100	100
Di-(p-Hydroxyphenyl) methyl ethyl methane	100	100
Di-(p-Hydroxyphenyl) methyl propyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl) di methyl methane	100	100
Di-(4-Hydroxy-3-methyl phenyl)-1 : 1-cyclo-hexane	100	100
2 : 4-Dihydroxy-triphenyl methane carboxylic acid lactone	100	100
4 : 4¹-Dihydroxy benzophenone	100	60
4 : 4¹-Dihydroxy diphenyl	100	100

* Rats remained in œstrus 40 days.



Synthetic Œstrogenic Agents without the Phenanthrene Nucleus

Synthetic Œstrogenic Agents without the Phenanthrene Nucleus

612.621.5:547.6

Molecular structure in relation to oestrogenic activity. Compounds without a phenanthrene nucleus

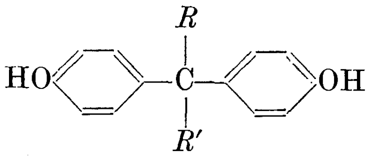
BY E. C. DODDS AND W. LAWSON

Proc. Roy. Soc. 1938

TABLE III

Derivatives of diphenyl methane:	Method of preparation	Dose (mg.)	% positive
4-Hydroxy-diphenyl methane	Clemmensen (1914)	100	Nil
3 : 3′-Dihydroxy-diphenyl methane	Auwers and Rietz (1907)	100	40
4 : 4′-Dihydroxy-diphenyl methane	Eberhardt and Welter (1894)	100	100
Diphenyl-methane-3 : 3′-dicarboxylic acid	Schöpf (1894)	100	Nil
Diphenyl-methane-4 : 4′-dicarboxylic acid	Schöpf (1894)	100	Nil
4 : 4′-Dihydroxy-diphenyl-methane-3 : 3′-dicarboxylic acid	Kahl (1906)	100	Nil
2 : 5-Dihydroxy-diphenyl-methane-carboxylic acid lactone	—	100	Nil
α-(2-Hydroxy-5-methyl-phenyl) phthalide	—	100	Nil
Benzilic acid	—	100	Nil
2 : 2′-Dihydroxy-di-α-naphthyl methane	Fries and Hübner (1906)	100	Nil
α : α-Diphenyl ethylene	Klages (1902)	100	Nil

Derivatives of 4 : 4′-dihydroxy diphenyl methane (Easson, Harrison, McSwiney and Pyman 1934):

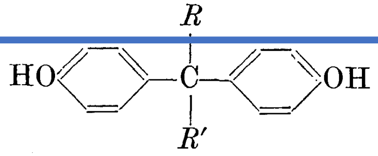


R	*R′*	Method of preparation	Dose (mg.)	% positive
Methyl	Methyl		100	100
Methyl	Ethyl		100	100
Methyl	*n*-Propyl		100	100
Ethyl	Ethyl		100	100
H	*n*-Hexyl		100	100
H	Phenyl	Russanow (1889)	100	100
			10	20
Methyl	Phenyl	—	100	60
Phenyl	Phenyl	—	100	Nil

TABLE III

Derivatives of diphenyl methane:	Method of preparation	Dose (mg.)	% positive
4-Hydroxy-diphenyl methane	Clemmensen (1914)	100	Nil
3 : 3′-Dihydroxy-diphenyl methane	Auwers and Rietz (1907)	100	40
4 : 4′-Dihydroxy-diphenyl methane	Eberhardt and Welter (1894)	100	100
Diphenyl-methane-3 : 3′-dicarboxylic acid	Schöpf (1894)	100	Nil
Diphenyl-methane-4 : 4′-dicarboxylic acid	Schöpf (1894)	100	Nil
4 : 4′-Dihydroxy-diphenyl-methane-3 : 3′-dicarboxylic acid	Kahl (1906)	100	Nil
2 : 5-Dihydroxy-diphenyl-methane-carboxylic acid lactone	—	100	Nil
α-(2-Hydroxy-5-methyl-phenyl) phthalide	—	100	Nil
Benzilic acid	—	100	Nil
2 : 2′-Dihydroxy-di-α-naphthyl methane	Fries and Hübner (1906)	100	Nil
α : α-Diphenyl ethylene	Klages (1902)	100	Nil

Derivatives of 4 : 4′-dihydroxy diphenyl methane (Easson, Harrison, McSwiney and Pyman 1934):



R	*R′*			
Methyl	Methyl		100	100
Methyl	Ethyl		100	100
Methyl	*n*-Propyl		100	100
[illegible]	Ethyl		100	100
[illegible]	*n*-Hexyl		100	100
[illegible]	Phenyl	Russanow (1889)	100	100
			10	20
[illegible]	Phenyl	—	100	60
Phenyl	Phenyl	—	100	Nil

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Synthetic Œstrogenic Agents without the Phenanthrene Nucleus

612.621.5:547.6

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BY E. C. DODDS AND W. LAWSON

Proc. Roy. Soc. 1938

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Molecular structure in relation to oestrogenic activity. Compounds without a phenanthrene nucleus

By E. C. Dodds and W. Lawson

Proc. Roy. Soc. 1938

Molecular structure in relation to oestrogenic activity: derivatives of 4:4′-dihydroxydiphenylmethane

By N. R. Campbell

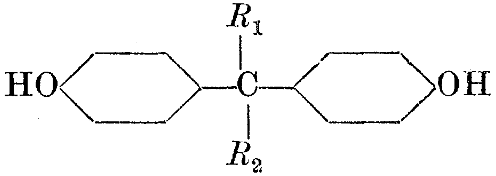
Proc. Roy. Soc. 1940

(*Communicated by Sir Robert Robinson, F.R.S.—Received* 26 *August* 1940)

996

JUNE 13, 1936

2. PRODUCTS FROM ALIPHATIC KETONES:



No.	Alkyl group R_1	Alkyl group R_2	Activity rat units/g.	
10 A	Methyl	Methyl	36	Zincke (1905)
10 B	Methyl	Methyl	40	Zincke (1913)
11 A	Methyl	Ethyl	100	Easson, Harrison, McSwiney and Pyman (1934)
11 B	Methyl	Ethyl	40	Easson, Harrison, McSwiney and Pyman (1934)
12 A	Methyl	*n*-Propyl	200	Easson, Harrison, McSwiney and Pyman (1934)
12 B	Methyl	*n*-Propyl	250	—
13 A	Methyl	*n*-Butyl	40	—
13 B	Methyl	*n*-Butyl	40	—
14 A	Methyl	*iso*-Butyl	250	—
14 B	Methyl	*iso*-Butyl	180	—
15 A	Ethyl	Ethyl	200	Dianin (1891)
15 B	Ethyl	Ethyl	1000	—
16 A	Ethyl	*n*-Propyl	1000	—
16 B	Ethyl	*n*-Propyl	4000	—
17 A	*n*-Propyl	*n*-Propyl	500	Dianin (1891)
17 B	*n*-Propyl	*n*-Propyl	5000	—
18 A	*n*-Propyl	*n*-Butyl	200	—
18 B	*n*-Propyl	*n*-Butyl	1000	—
19 A	*n*-Butyl	*n*-Butyl	20	—
19 B	*n*-Butyl	*n*-Butyl	200	—

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Roy. Soc. 1938

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Roy. Soc. 1940

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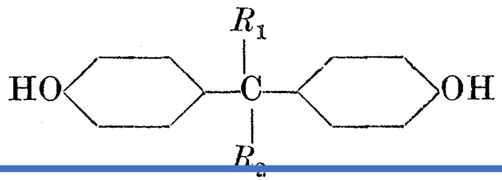
2. PRODUCTS FROM ALIPHATIC KETONES: 

No.	Alkyl group R_1	Alkyl group R_2	Activity rat units/g.	
10 A	Methyl	Methyl	36	Zi
10 B	Methyl	Methyl	40	Z
11 A	Methyl	Ethyl	100	E Swiney and (1934)
11 B	Methyl	Ethyl	40	Easson, Harrison, McSwiney and Pyman (1934)
12 A	Methyl	*n*-Propyl	200	Easson, Harrison, McSwiney and Pyman (1934)
12 B	Methyl	*n*-Propyl	250	—
13 A	Methyl	*n*-Butyl	40	—
13 B	Methyl	*n*-Butyl	40	—
14 A	Methyl	*iso*-Butyl	250	—
14 B	Methyl	*iso*-Butyl	180	—
15 A	Ethyl	Ethyl	200	Dianin (1891)
15 B	Ethyl	Ethyl	1000	—
16 A	Ethyl	*n*-Propyl	1000	—
16 B	Ethyl	*n*-Propyl	4000	—
17 A	*n*-Propyl	*n*-Propyl	500	Dianin (1891)
17 B	*n*-Propyl	*n*-Propyl	5000	—
18 A	*n*-Propyl	*n*-Butyl	200	—
18 B	*n*-Propyl	*n*-Butyl	1000	—
19 A	*n*-Butyl	*n*-Butyl	20	—
19 B	*n*-Butyl	*n*-Butyl	200	—

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Roy. Soc. 1938

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1940)

Synthetic Œstrogenic Agents without the Phenanthrene Nucleus

612.621.5:547.6

Molecular structure in relation to oestrogenic activity. Compounds without a phenanthrene nucleus

BY E. C. DODDS AND W. LAWSON

Proc. Roy. Soc. 1938

Molecular structure in relation to oestrogenic activity: derivatives of 4 : 4′-dihydroxydiphenylmethane

BY N. R. CAMPBELL

Proc. Roy. Soc. 1940

(*Communicated by Sir Robert Robinson, F.R.S.—Received* 26 *August* 1940)

The Relation of Estrogenic Activity to Structure in Some 4,4′-Dihydroxydiphenylmethanes[1]

BY E. EMMET REID AND EDITH WILSON[2] J. Am. Chem. Soc. 1944

The R phenyl-

. Soc. 1944

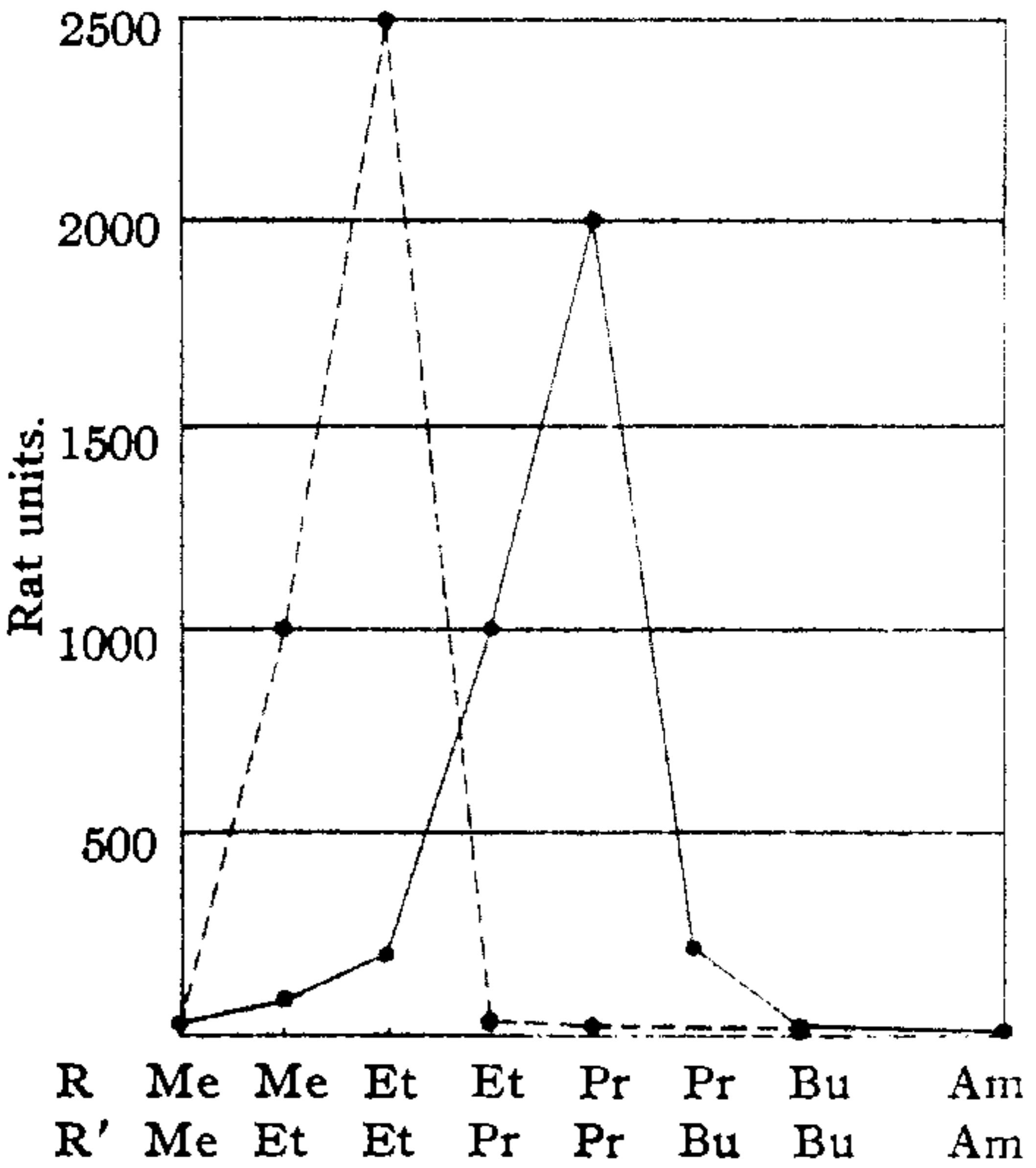
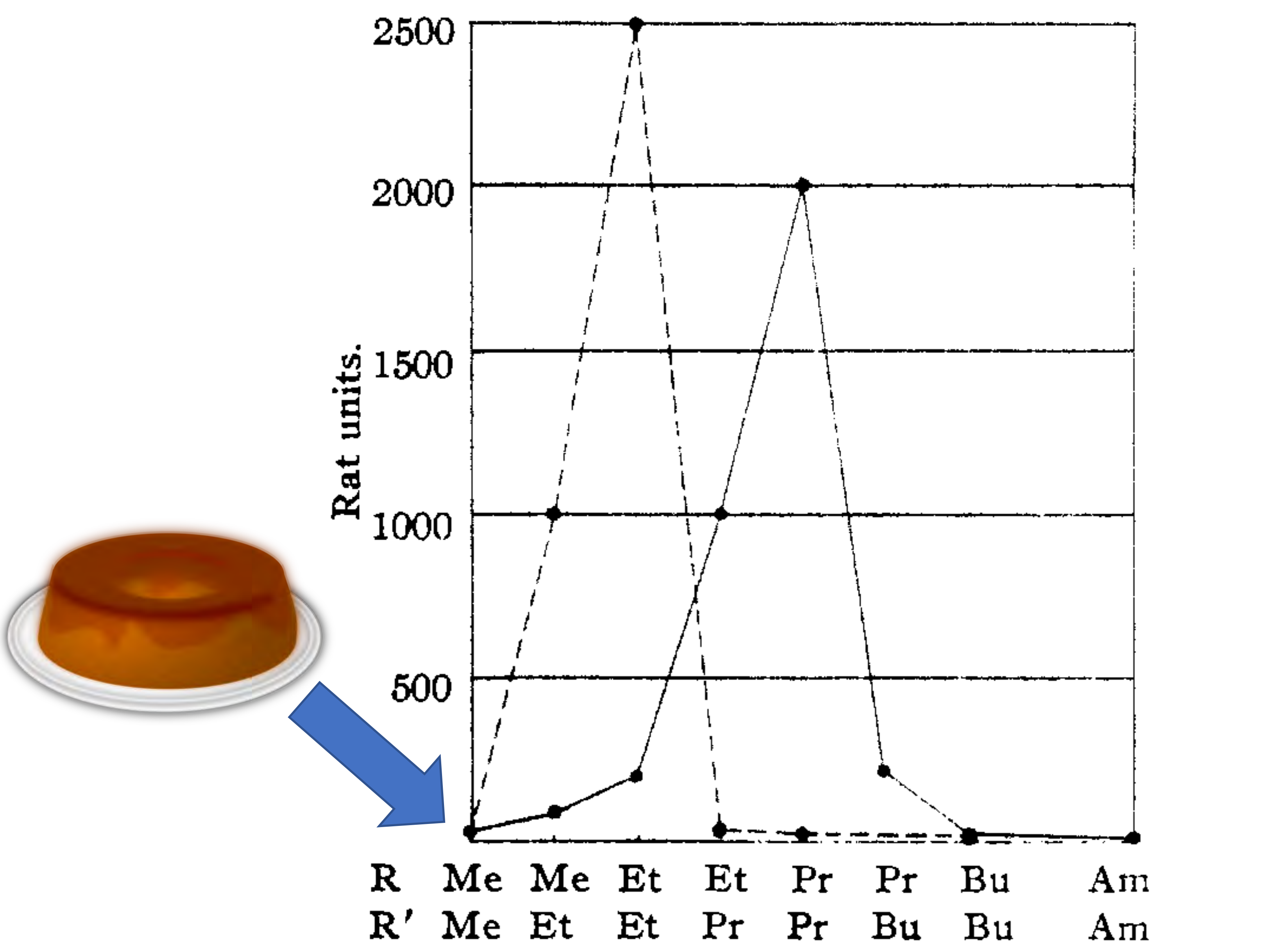


Fig. 1.—Estrogenic activity related to sizes of R and R′: —●——●—, rat u./g. $(HOC_6H_4)_2CRR'$; - -●- - - -●- -, rat u./mg. $HOC_6H_4CR:CR'C_6H_4OH$.

The R… …phenyl-

… . Soc. 1944



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SYNTHETIC ESTROGENS AND THE RELATION BETWEEN THEIR STRUCTURE AND THEIR ACTIVITY

ULRICH V. SOLMSSEN

Research Laboratories of Hoffman-La Roche, Inc., Nutley 10, New Jersey

Received April 13, 1945

Chem. Rev. 1945

TABLE 15

Diphenylmethane derivatives

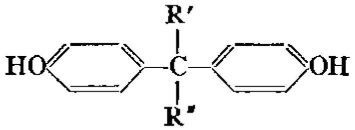
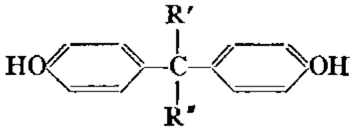
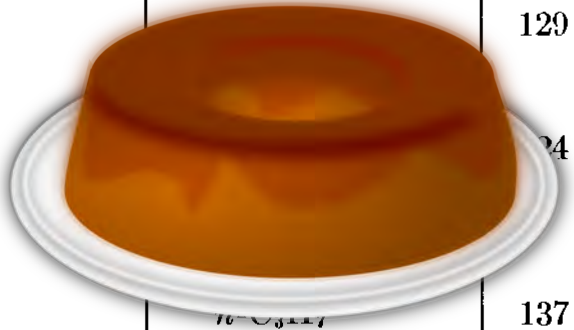
FORMULA  R′	R″	MELTING POINT	NAME	ESTROGENIC ACTIVITY IN RATS SUBCUTANEOUSLY (100 PER CENT RESPONSE UNLESS INDICATED OTHERWISE) Minimum effective dose	Rat units per gram	REFERENCES
		°C.		*micrograms*		
H	H		Bis(4-hydroxyphenyl)methane	100,000		(61, 192)
					20	(21)
H	CH_3	122	1,1-Bis(4-hydroxyphenyl)ethane		20	(21, 89)
CH_3	CH_3	155	2,2-Bis(4-hydroxyphenyl)propane	100,000		(61, 64)
					36	(21, 231)
					28	(158)
H	C_2H_5	129	1,1-Bis(4-hydroxyphenyl)propane	100,000		(61)
					16	(21, 89)
CH_3	C_2H_5	124	2,2-Bis(4-hydroxyphenyl)butane	100,000		(61, 64, 67, 120)
					124	(158)
					100	(21)
H	*n*-C_3H_7	137	1,1-Bis(4-hydroxyphenyl)butane		40	(21, 89)
H	Iso-C_3H_7	152	1,1-Bis(4-hydroxyphenyl)-2-methyl-propane		36	(21)
CH_3	*n*-C_3H_7	149	2,2-Bis(4-hydroxyphenyl)pentane	100,000		(61, 64, 67, 120)
					200	(21, 158)

TABLE 15

Diphenylmethane derivatives

FORMULA  R′	R″	MELTING POINT	NAME	ESTROGENIC ACTIVITY IN RATS SUBCUTANEOUSLY (100 PER CENT RESPONSE UNLESS INDICATED OTHERWISE) Minimum effective dose	Rat units per gram	REFERENCES
		°C.		*micrograms*		
H	H		Bis(4-hydroxyphenyl)methane	100,000 	 20	(61, 192) (21)
H	CH_3	122	1,1-Bis(4-hydroxyphenyl)ethane		20	(21, 89)
CH_3	CH_3	155	2,2-Bis(4-hydroxyphenyl)propane	100,000 	 36 28	(61, 64) (21, 231) (158)
H	[illegible]	129	1,1-Bis(4-hydroxyphenyl)propane	100,000 	 16	(61) (21, 89)
CH_3	[illegible]	[illegible]4	2,2-Bis(4-hydroxyphenyl)butane	100,000 	 124 100	(61, 64, 67, 120) (158) (21)
H	n-C_3H_7	137	1,1-Bis(4-hydroxyphenyl)butane		40	(21, 89)
H	Iso-C_3H_7	152	1,1-Bis(4-hydroxyphenyl)-2-methyl-propane		36	(21)
CH_3	n-C_3H_7	149	2,2-Bis(4-hydroxyphenyl)pentane	100,000 	 200	(61, 64, 67, 120) (21, 158)



1944

.945

A. Dianin, **1891**, J. Russian Physical Chemistry Society, **23**: 488-517.

Zincke reported key physical properties of BPA (e.g., molecular composition, melting point, solubility in common solvents) but did not propose any application or use for BPA or the other materials he synthesized..

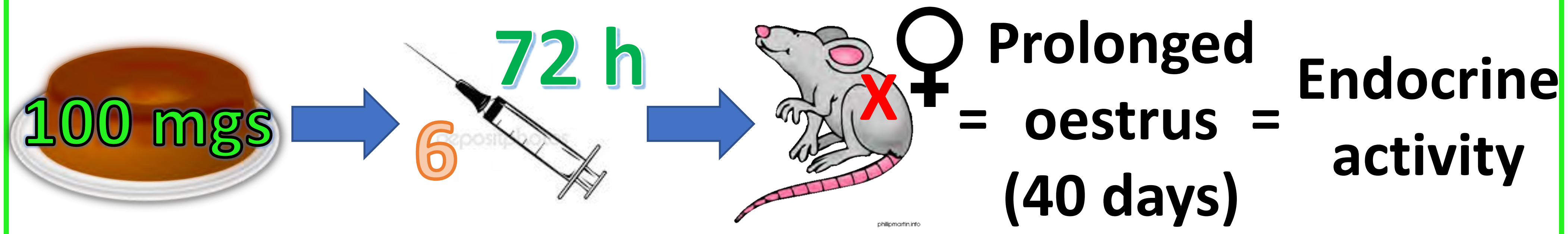
Bisphenol A Developed Commercially in the 1950s

In 1953, Dr. Hermann Schnell of Bayer in Germany and Dr. Dan Fox of General Electric in the United States independently developed manufacturing processes for a new plastic material, polycarbonate, using BPA as the starting material.

Bisphenol A First Synthesized in Germany

www.bisphenol-A.org

A. Dianin, **1891**, J. Russian Physical Chemistry Society, **23**: 488-517.



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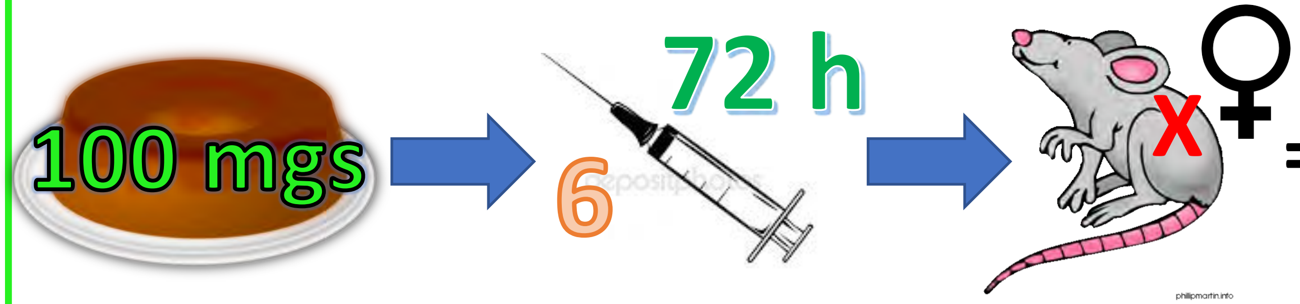

Prolonged = oestrus = (40 days)

Endocrine activity

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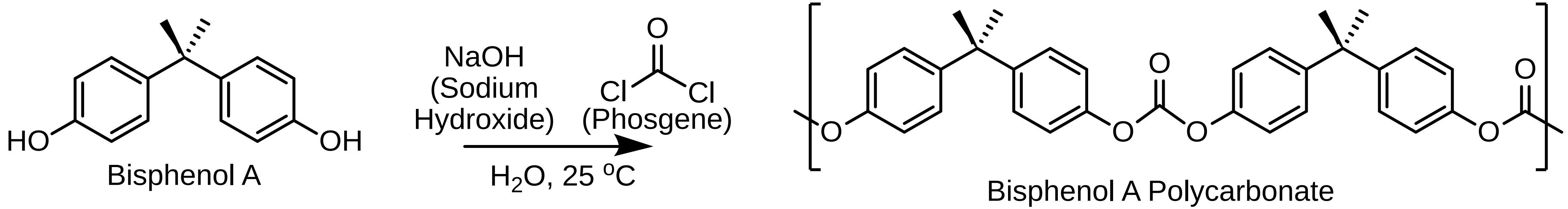

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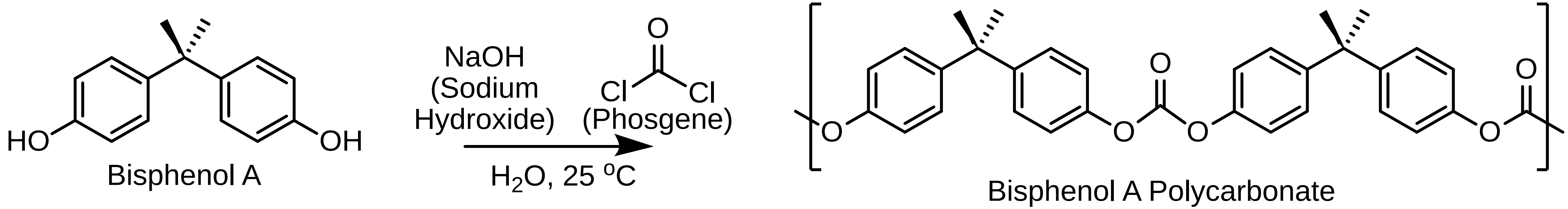

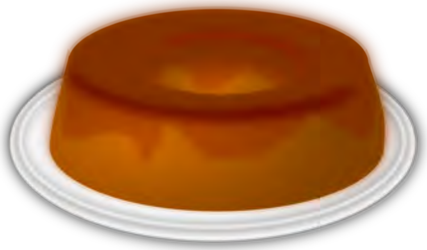

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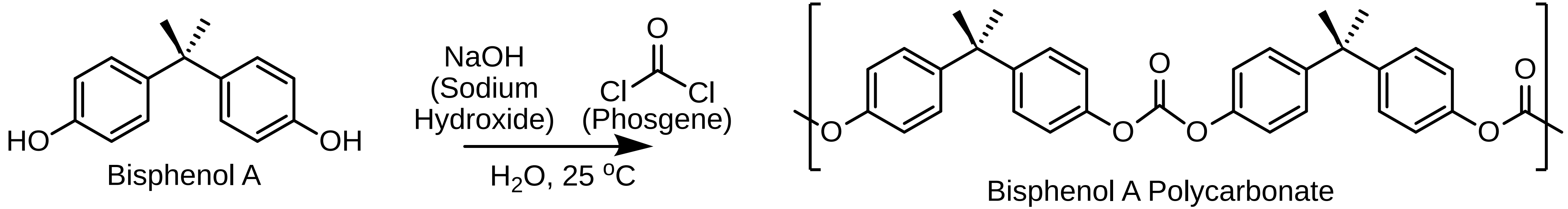

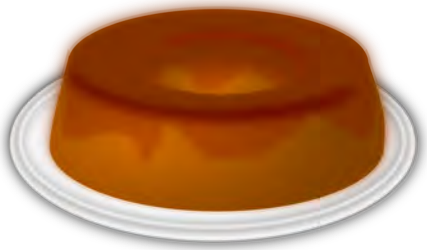

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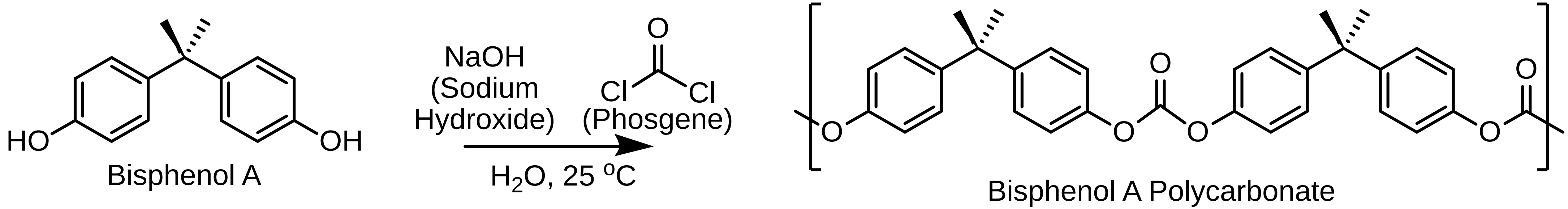

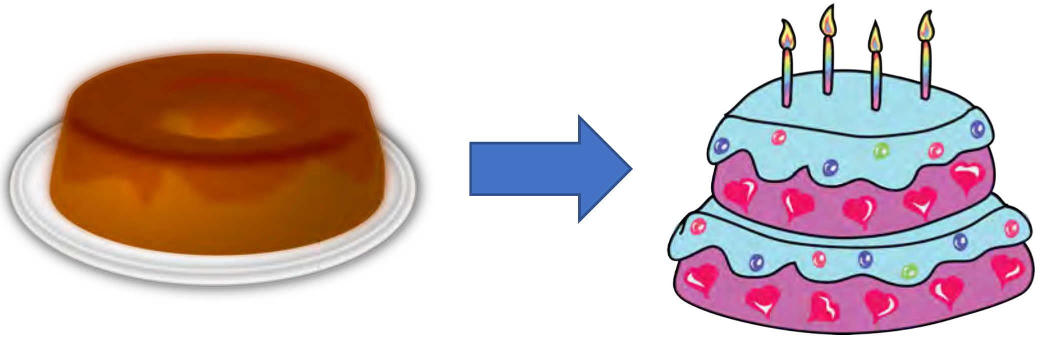

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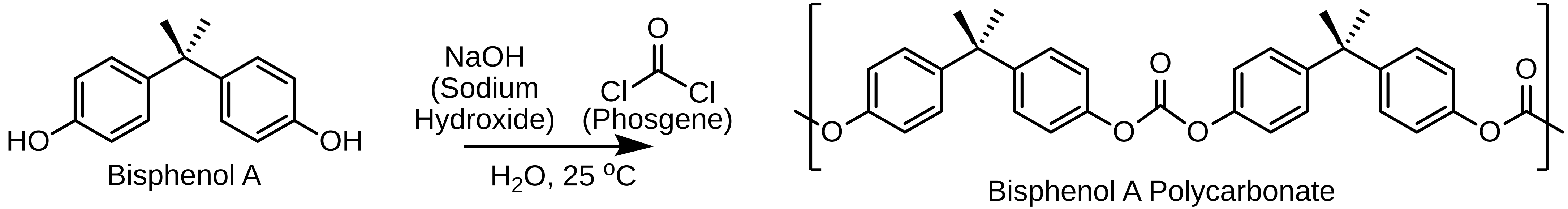

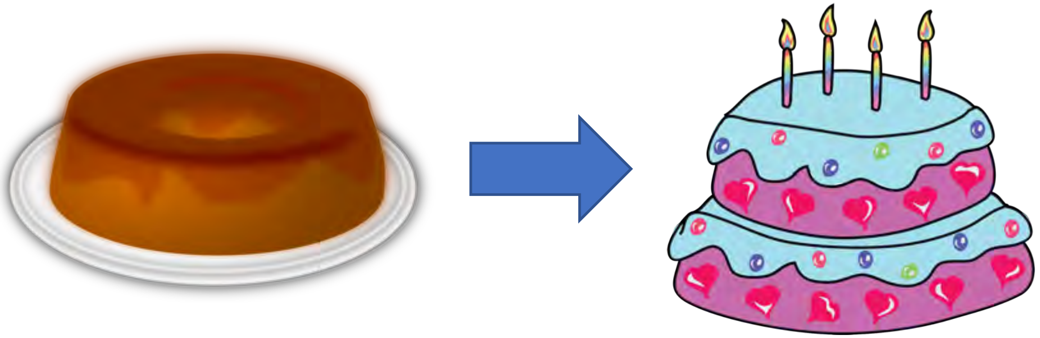

~95% of the produced BPA

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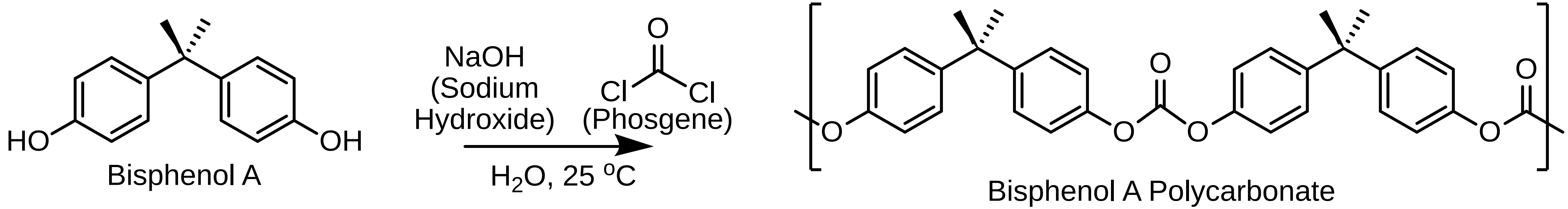

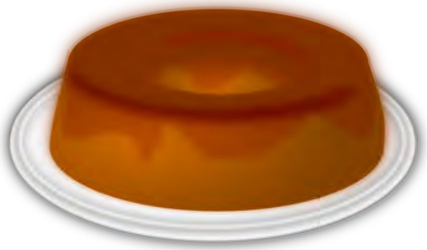

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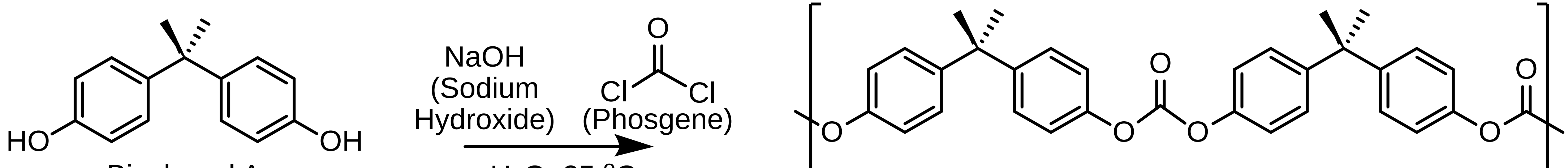
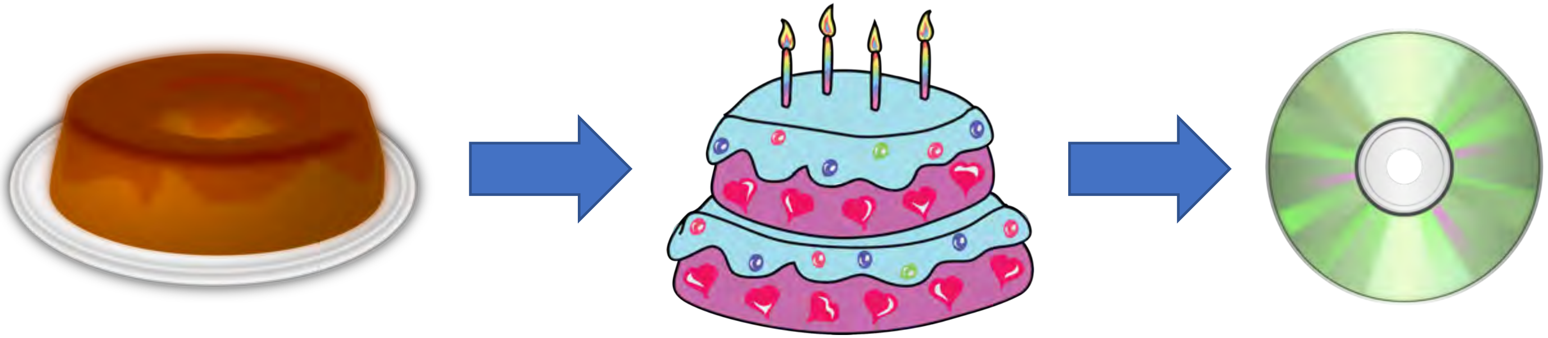


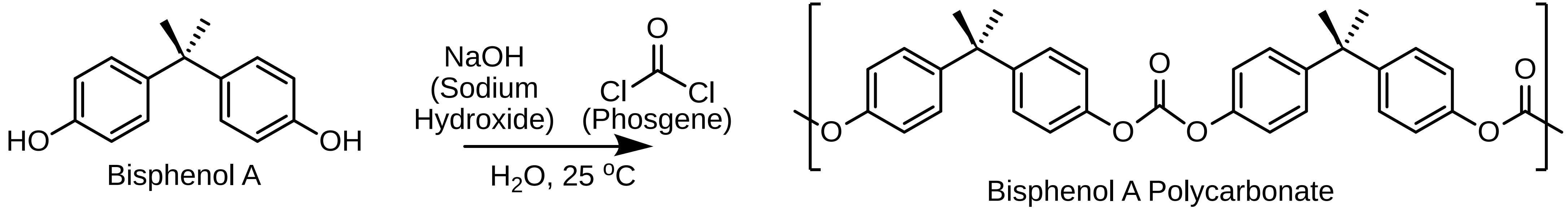
Bisphenol A

Bisphenol A Polycarbonate



~95% of the produced BPA

In 1953, Dr. Hermann Schnell of Bayer in Germany and Dr. Dan Fox of General Electric in the United States independently developed manufacturing processes for a new plastic material, polycarbonate, using BPA as the starting material.



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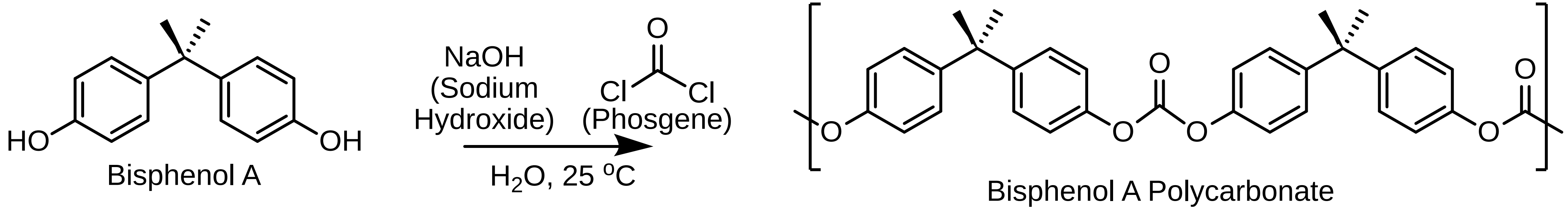

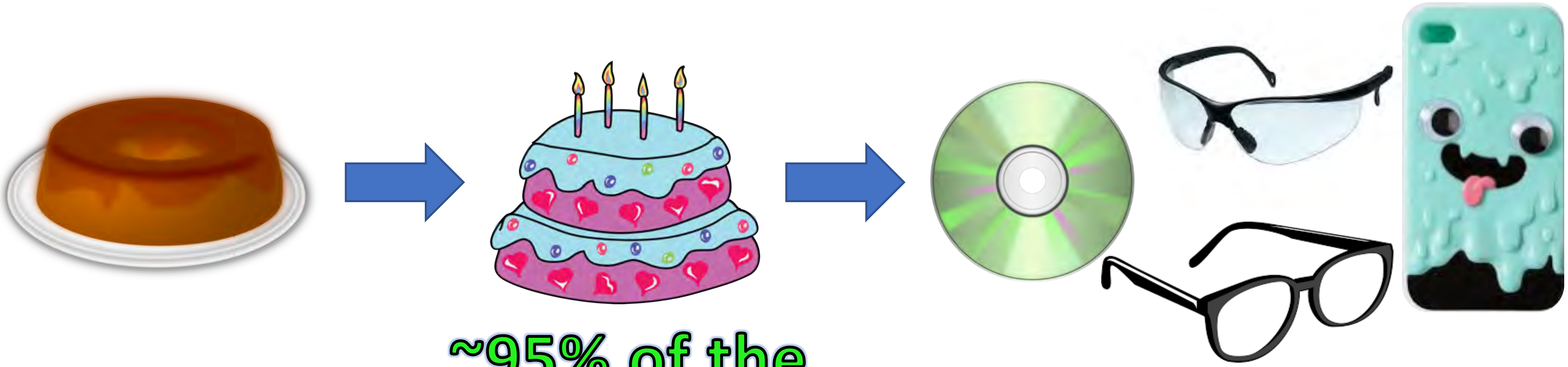

~95% of the produced BPA

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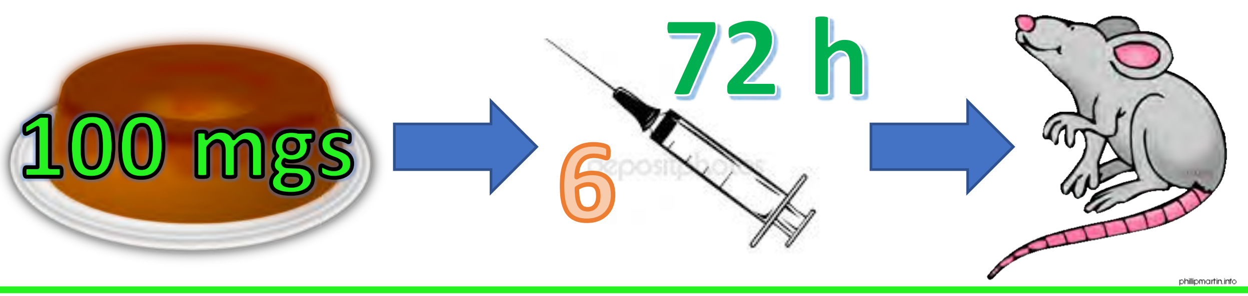
Bisphenol A First Synthesized in Germany

www.bisphenol-A.org

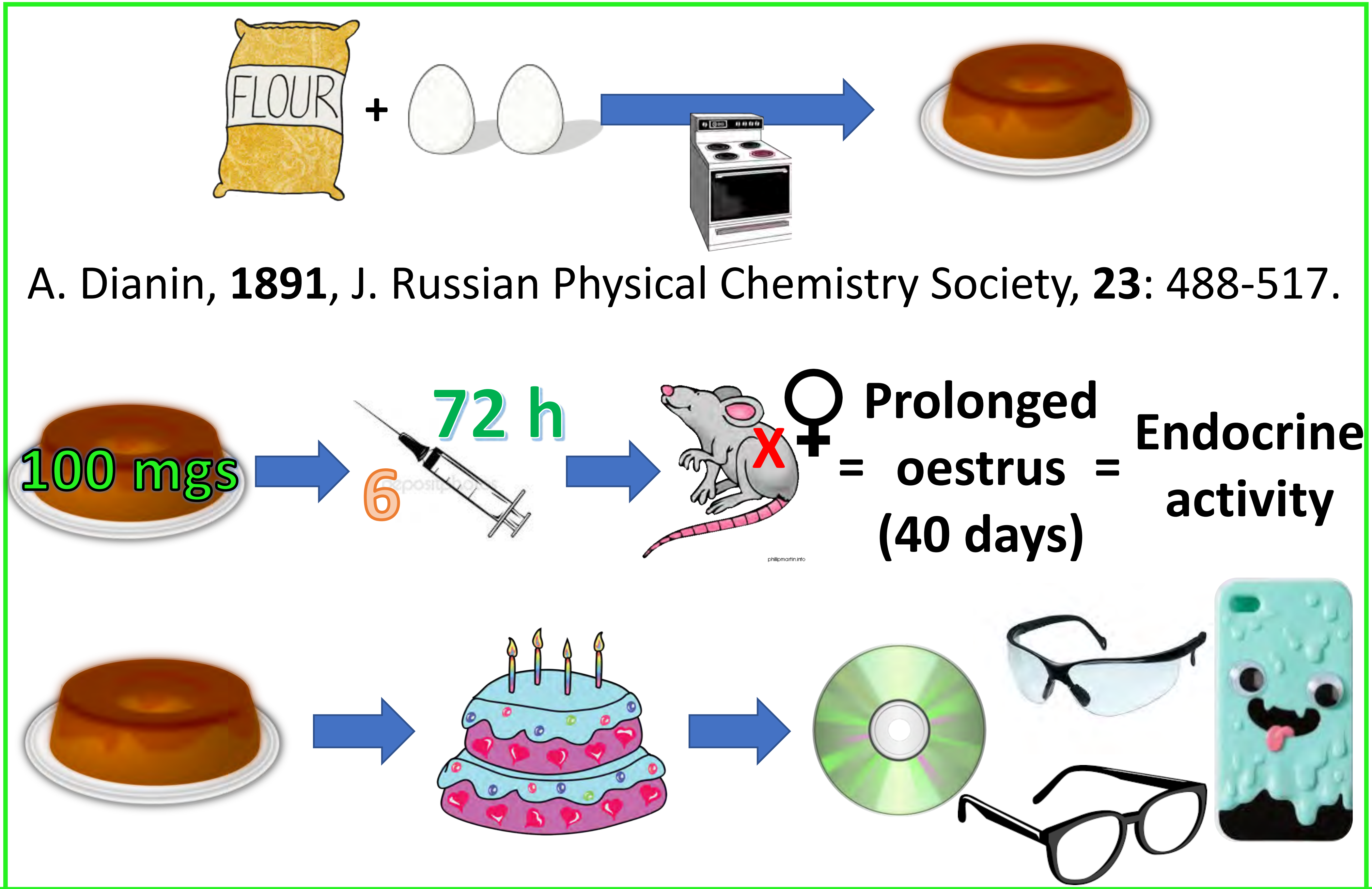
A. Dianin, **1891**, J. Russian Physical Chemistry Society, **23**: 488-517.



= **Prolonged oestrus (40 days)**

Bisphenol A Developed Commercially in the 1950s

In 1953, Dr. Hermann Schnell of Bayer in Germany and Dr. Dan Fox of General Electric in the United States independently developed manufacturing processes for a new plastic material, polycarbonate, using BPA as the starting material.


FLOUR
+
A. Dianin, 1891, J. Russian Physical Chemistry Society, 23: 488-517.
100 mgs
6
72 h
X
Prolonged
= oestrus =
(40 days)
Endocrine
activity

Contaminated
RCF Products

Contaminated RCF Products

- *Newspapers*

Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*

Contaminated RCF Products

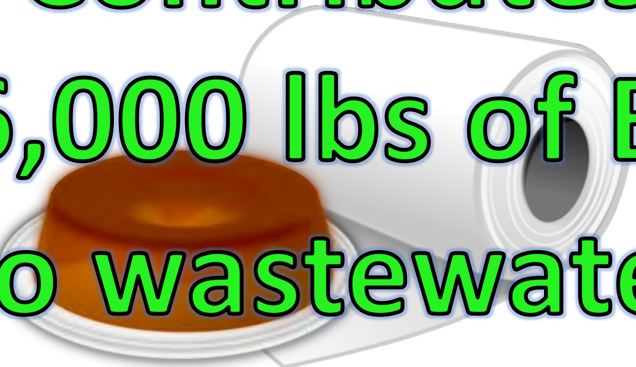
- *Newspapers*
- *Toilet Paper*

Contributes 36,000 lbs of BPA to wastewater per year

Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*

Contributes 36,000 lbs of BPA to wastewater per year



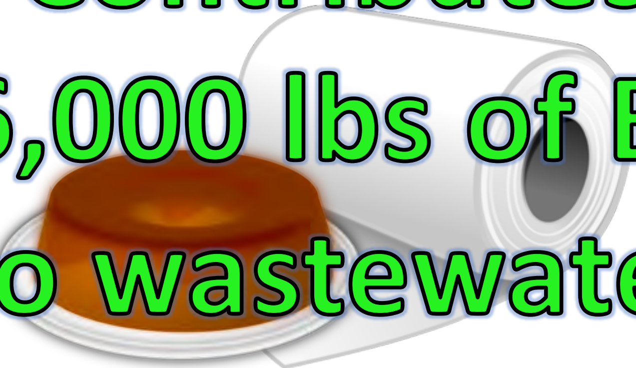
Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*

Contributes 36,000 lbs of BPA to wastewater per year

Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*
- *Fried Potato Boxes*



Contributes 36,000 lbs of BPA to wastewater per year

Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*
- *Fried Potato Boxes*
- *Sandwich Boxes*

Contributes 36,000 lbs of BPA to wastewater per year

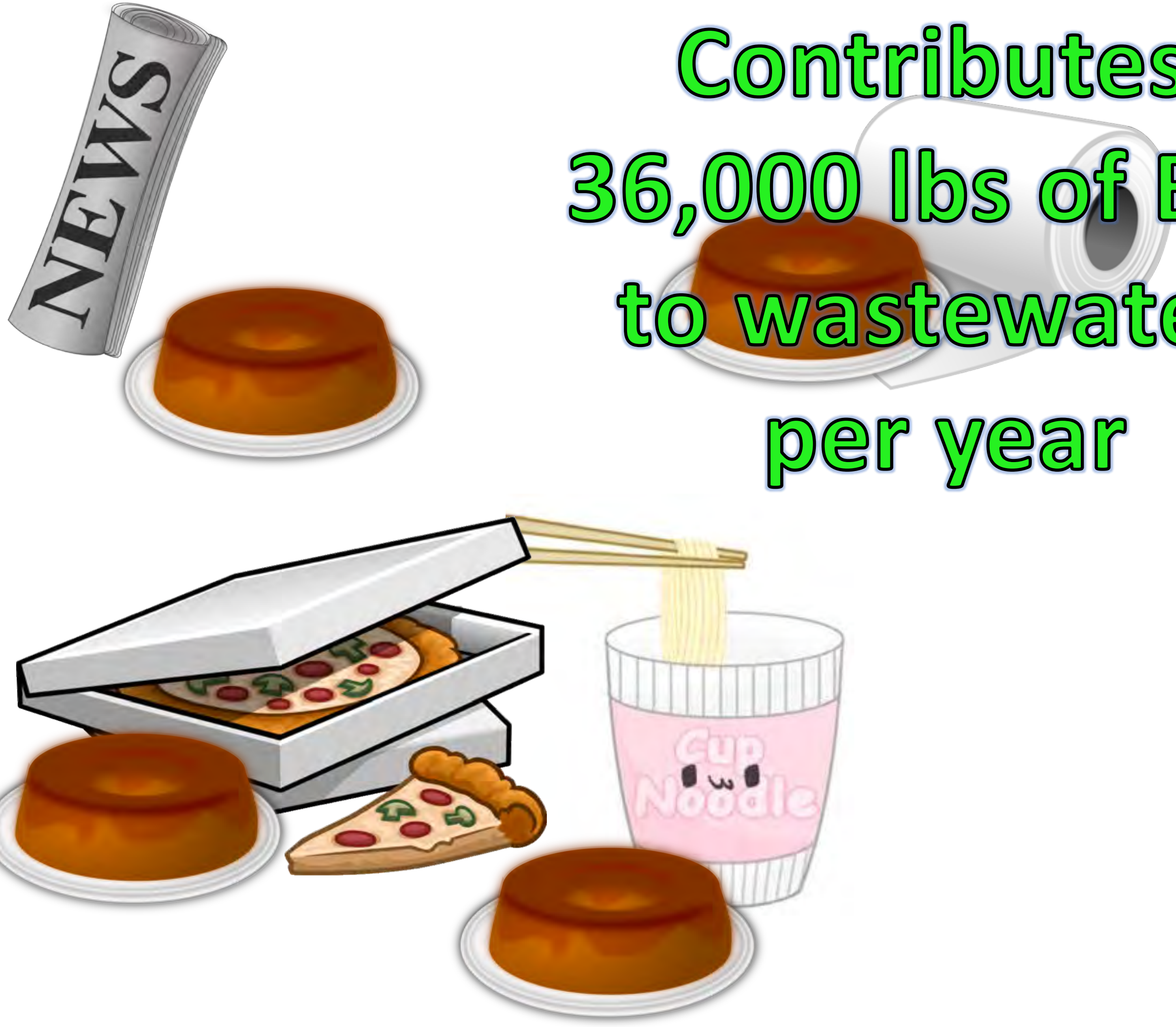
Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*
- *Fried Potato Boxes*
- *Sandwich Boxes*
- *Noodle Cups*

Contributes 36,000 lbs of BPA to wastewater per year

Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*
- *Fried Potato Boxes*
- *Sandwich Boxes*
- *Noodle Cups*
- *Confectionary Boxes*

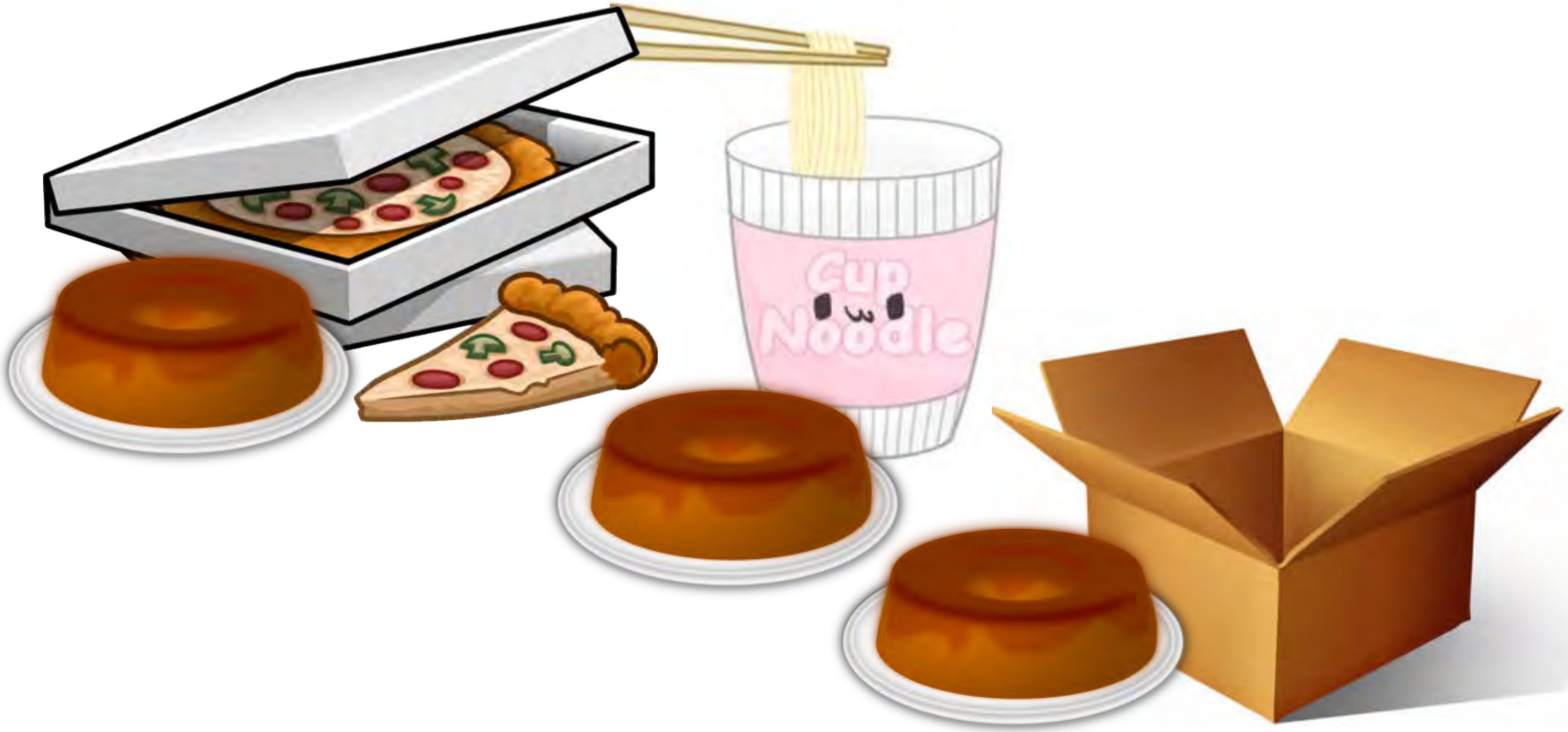


Contributes 36,000 lbs of BPA to wastewater per year

Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*
- *Fried Potato Boxes*
- *Sandwich Boxes*
- *Noodle Cups*
- *Confectionary Boxes*
- *General Food Storage Boxes*

Contributes 36,000 lbs of BPA to wastewater per year



Contaminated RCF Products

- *Newspapers*
- *Toilet Paper*
- *Pizza Boxes*
- *Fried Chicken Boxes*
- *Fried Potato Boxes*
- *Sandwich Boxes*
- *Noodle Cups*
- *Confectionary Boxes*
- *General Food Storage Boxes*

Contributes 36,000 lbs of BPA to wastewater per year

Includes food contact surfaces

Liao 2011
Gehring 2004
Ozaki 2004
Lopez-Espinosa 2007
USEPA 2015