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Review

Geosmin as a source of the earthy-musty smell in fruits, vegetables and water: Origins, impact on foods and water, and review of the removing techniques

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Contents

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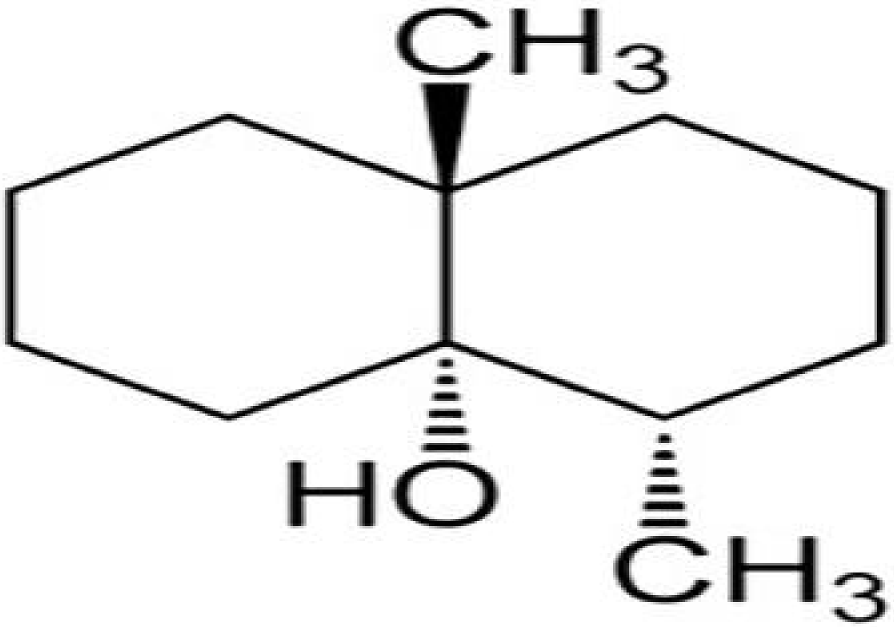
TITLE

研究背景

研究背景

水产品味道鲜美，并具有低脂肪、高蛋白、营养平衡性好等特点，具有重要的营养价值。水产业是养殖业的重要组成部分。以我国为例，2017年全国水产品的累计成交量达到1145.12万吨，成交额2298.71亿元。水产品对于保障我国食物供应、提高人们健康水平发挥着重要作用。

气味是水产品的一个重要感官评定要素，它从某方面反映了水产品的品质。大多数人是通过味道来判断食物是否可以被食用，这些异味不仅影响到鱼类的适口性，也成为了我国水产发展的阻碍，此问题亟待解决。



GSM：土臭素
分子结构：反式-1,10-二甲基-反式-9-十氢萘

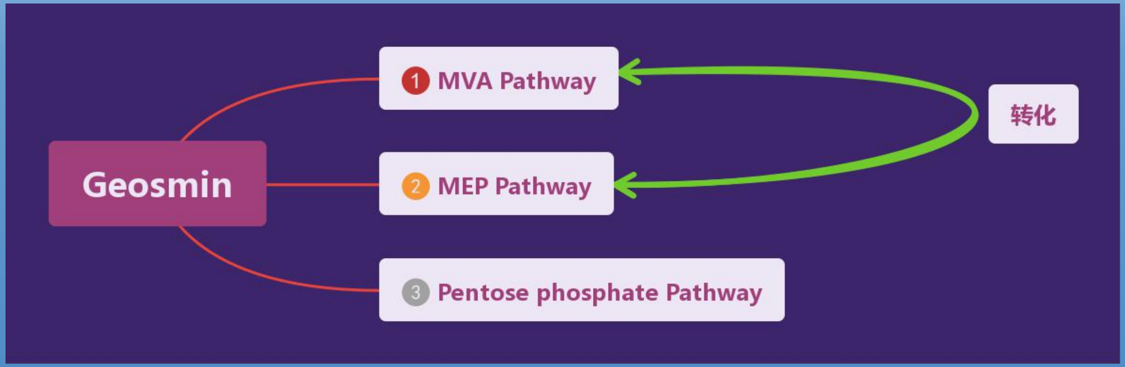
- 由放线菌、藻类等生物合成
- 同二甲基异莰醇（2-MIB）一样属于异萜类化合物（是亲脂性的次级代谢产物）
- 沸点约为270℃，含有碳和氢，但不含氮
- 发现其与酸反应得到无味的中性油
- 沸点约230℃
- 其他性能如折射率（1.4650±0.0029 CL）
- 密度（0.9494±0.0127 g cm -3）
- 水溶性（150.2±4.1 g L -1 ）
- 辛醇/水分配系数（3.70±0.03 CL）
- 亨利定律常数（6.66.10 -5 atm m 3 mol -1）
- 通过腮、皮肤、肠道等方式进入体内
- 嗅阈值很低，在6~10ng/L

2

TITLE

土臭素的生物合成途径及分析测定方法

发现Geosmin、2-MIB等物质均属萜类化合物，故其存在以下三种合成路径。



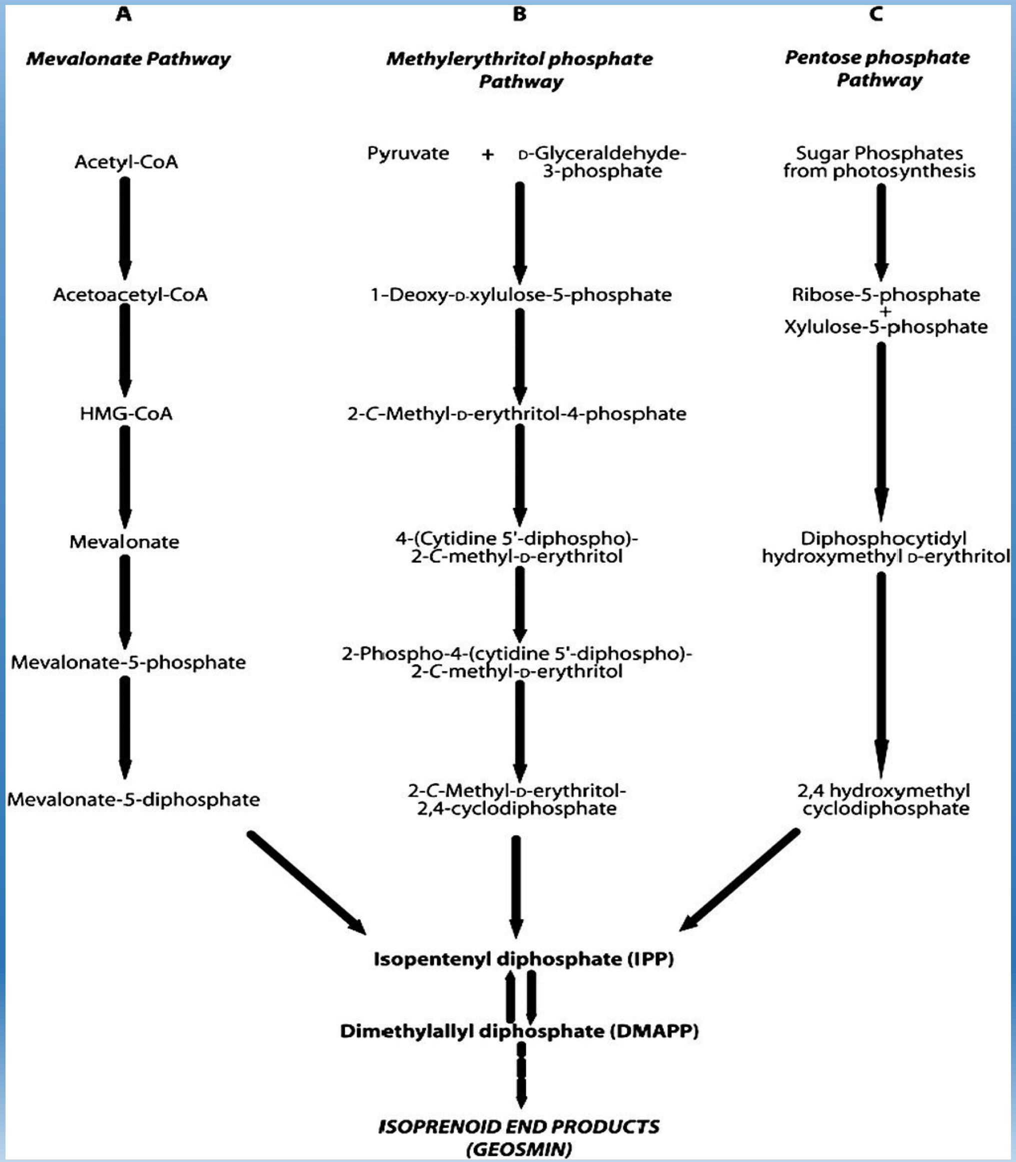
Geosmin

- ❶ MVA Pathway
- ❷ MEP Pathway
- ❸ Pentose phosphate Pathway

转化

化感作用

- ❶ 抑制种子萌发及幼苗生长
- ❷ 调节群体密度---自毒作用
- ❸ 影响种群格局和群落演替



- 土臭素分析和测定
  - 感官分析
    - 嗅阈检测法
    - 嗅觉层次分析法
  - 仪器分析
    - GC-MS
    - 液-液萃取
    - 固相萃取
    - CLSA封闭循环吹脱法
    - 搅拌吸附萃取法
  - 其他方法
    - 单克隆抗体建立ELISA法测MIB
    - 利用感官分析法建立了类似的机械感应器

我国则缺少鲤等主要养殖鱼类土腥味检测的技术方法和标准，无法为渔业生产中监测养殖鱼土腥异味程度提供一种实用而简单的方法。

我国台湾基于该方法已经建立检测标准并予公布

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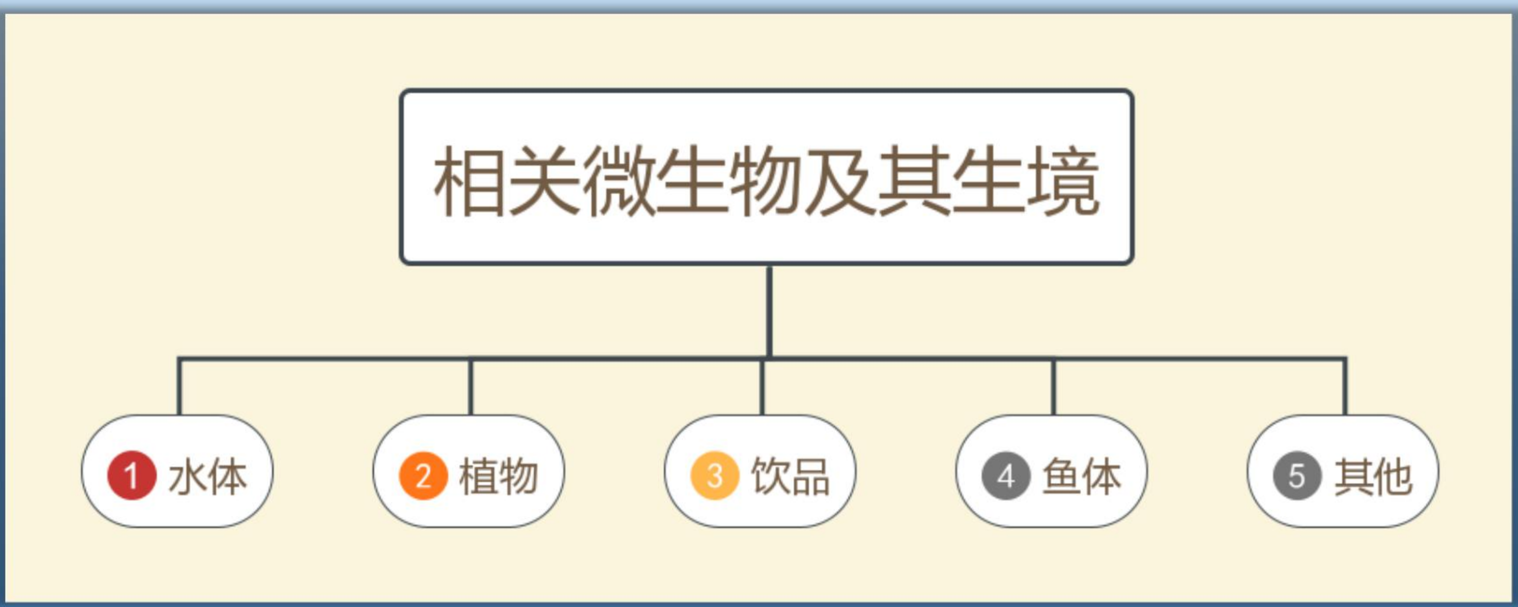
TITLE

土臭素的生物合成相关微生物生境及去除Geosmin技术



相关微生物及其生境

- ① 水体
- ② 植物
- ③ 饮品
- ④ 鱼体
- ⑤ 其他

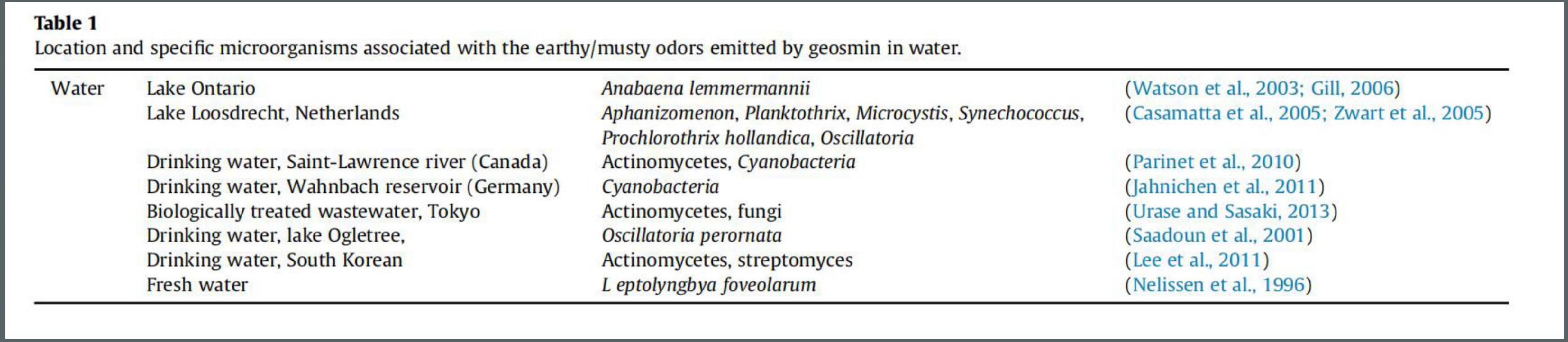


Table 1
Location and specific microorganisms associated with the earthy/musty odors emitted by geosmin in water.

Water	Lake Ontario	*Anabaena lemmermannii*	(Watson et al., 2003; Gill, 2006)
	Lake Loosdrecht, Netherlands	*Aphanizomenon*, *Planktothrix*, *Microcystis*, *Synechococcus*, *Prochlorothrix hollandica*, *Oscillatoria*	(Casamatta et al., 2005; Zwart et al., 2005)
	Drinking water, Saint-Lawrence river (Canada)	Actinomycetes, *Cyanobacteria*	(Parinet et al., 2010)
	Drinking water, Wahnbach reservoir (Germany)	*Cyanobacteria*	(Jahnichen et al., 2011)
	Biologically treated wastewater, Tokyo	Actinomycetes, fungi	(Urase and Sasaki, 2013)
	Drinking water, lake Ogletree,	*Oscillatoria perornata*	(Saadoun et al., 2001)
	Drinking water, South Korean	Actinomycetes, streptomyces	(Lee et al., 2011)
	Fresh water	*Leptolyngbya foveolarum*	(Nelissen et al., 1996)

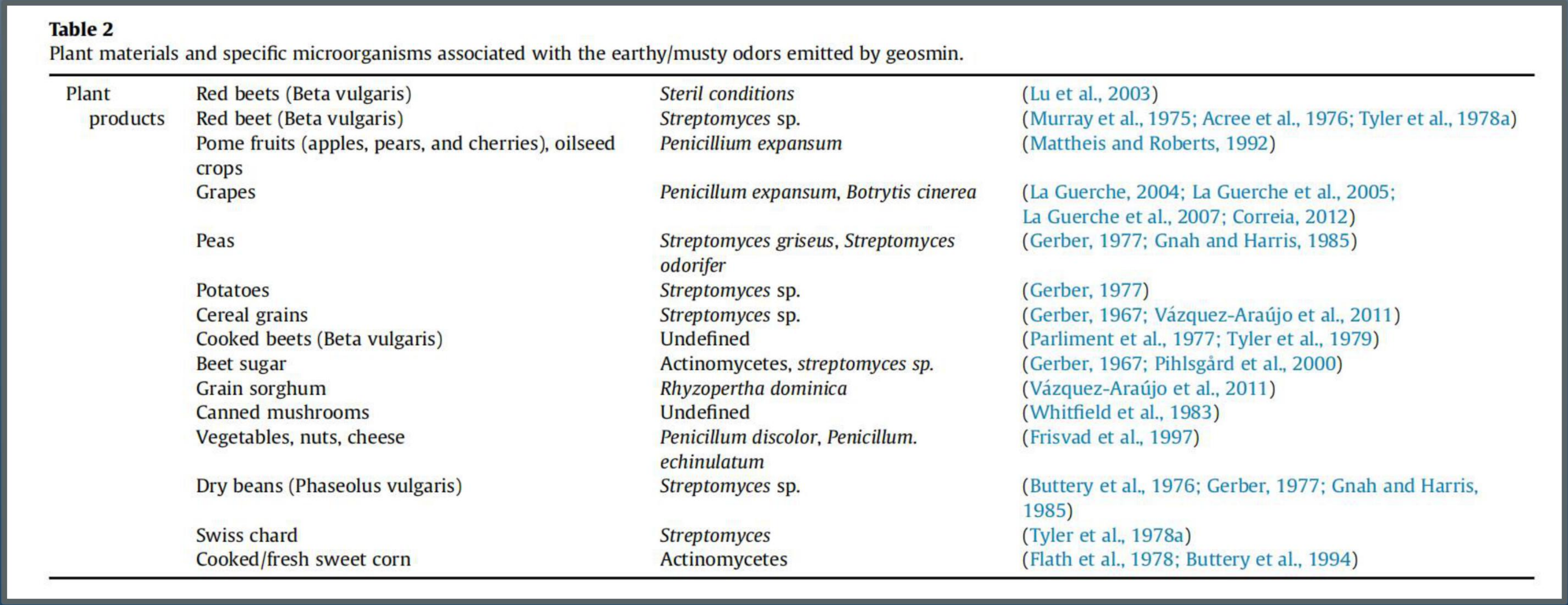


Table 2
Plant materials and specific microorganisms associated with the earthy/musty odors emitted by geosmin.

Plant products	Red beets (Beta vulgaris)	*Steril conditions*	(Lu et al., 2003)
	Red beet (Beta vulgaris)	*Streptomyces* sp.	(Murray et al., 1975; Acree et al., 1976; Tyler et al., 1978a)
	Pome fruits (apples, pears, and cherries), oilseed crops	*Penicillium expansum*	(Mattheis and Roberts, 1992)
	Grapes	*Penicillum expansum*, *Botrytis cinerea*	(La Guerche, 2004; La Guerche et al., 2005; La Guerche et al., 2007; Correia, 2012)
	Peas	*Streptomyces griseus*, *Streptomyces odorifer*	(Gerber, 1977; Gnah and Harris, 1985)
	Potatoes	*Streptomyces* sp.	(Gerber, 1977)
	Cereal grains	*Streptomyces* sp.	(Gerber, 1967; Vázquez-Araújo et al., 2011)
	Cooked beets (Beta vulgaris)	Undefined	(Parliment et al., 1977; Tyler et al., 1979)
	Beet sugar	Actinomycetes, *streptomyces sp.*	(Gerber, 1967; Pihlsgård et al., 2000)
	Grain sorghum	*Rhyzopertha dominica*	(Vázquez-Araújo et al., 2011)
	Canned mushrooms	Undefined	(Whitfield et al., 1983)
	Vegetables, nuts, cheese	*Penicillum discolor*, *Penicillum. echinulatum*	(Frisvad et al., 1997)
	Dry beans (Phaseolus vulgaris)	*Streptomyces* sp.	(Buttery et al., 1976; Gerber, 1977; Gnah and Harris, 1985)
	Swiss chard	*Streptomyces*	(Tyler et al., 1978a)
	Cooked/fresh sweet corn	Actinomycetes	(Flath et al., 1978; Buttery et al., 1994)

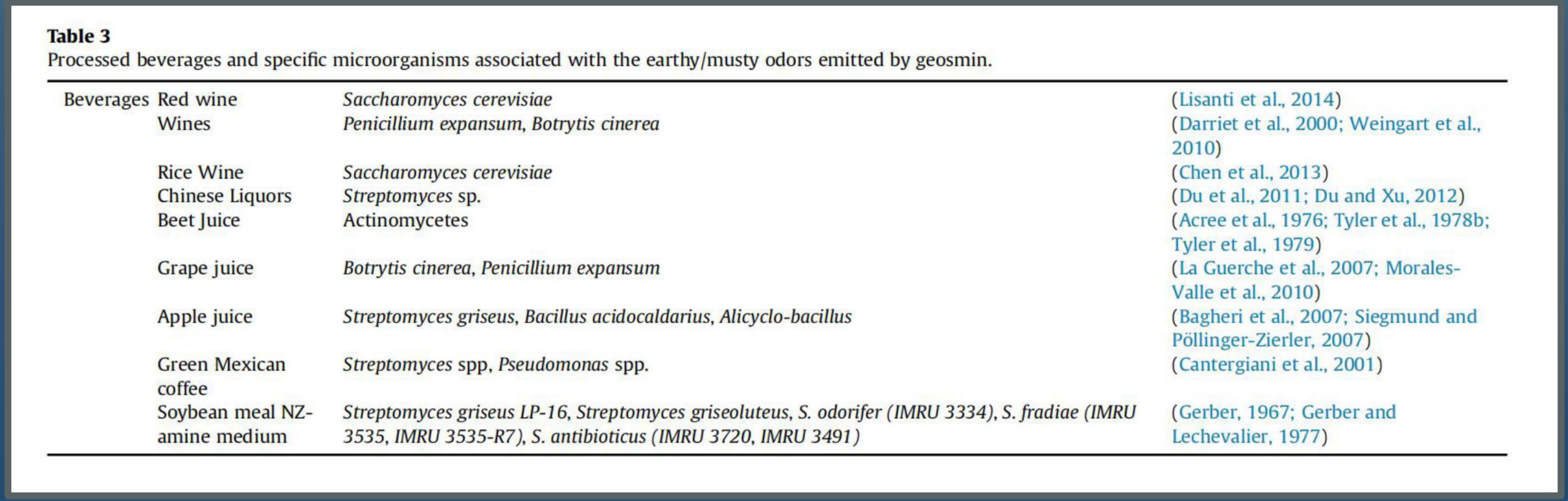


Table 3

Processed beverages and specific microorganisms associated with the earthy/musty odors emitted by geosmin.

Beverages	Red wine	*Saccharomyces cerevisiae*	(Lisanti et al., 2014)
	Wines	*Penicillium expansum, Botrytis cinerea*	(Darriet et al., 2000; Weingart et al., 2010)
	Rice Wine	*Saccharomyces cerevisiae*	(Chen et al., 2013)
	Chinese Liquors	*Streptomyces* sp.	(Du et al., 2011; Du and Xu, 2012)
	Beet Juice	Actinomycetes	(Acree et al., 1976; Tyler et al., 1978b; Tyler et al., 1979)
	Grape juice	*Botrytis cinerea, Penicillium expansum*	(La Guerche et al., 2007; Morales-Valle et al., 2010)
	Apple juice	*Streptomyces griseus, Bacillus acidocaldarius, Alicyclo-bacillus*	(Bagheri et al., 2007; Siegmund and Pöllinger-Zierler, 2007)
	Green Mexican coffee	*Streptomyces* spp, *Pseudomonas* spp.	(Cantergiani et al., 2001)
	Soybean meal NZ-amine medium	*Streptomyces griseus LP-16, Streptomyces griseoluteus, S. odorifer (IMRU 3334), S. fradiae (IMRU 3535, IMRU 3535-R7), S. antibioticus (IMRU 3720, IMRU 3491)*	(Gerber, 1967; Gerber and Lechevalier, 1977)

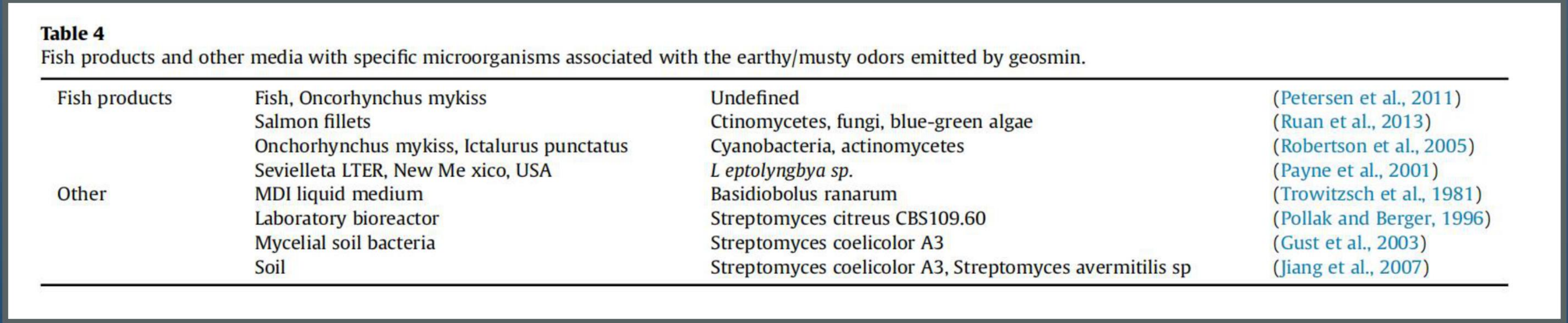


Table 4

Fish products and other media with specific microorganisms associated with the earthy/musty odors emitted by geosmin.

Fish products	Fish, Oncorhynchus mykiss	Undefined	(Petersen et al., 2011)
	Salmon fillets	Ctinomycetes, fungi, blue-green algae	(Ruan et al., 2013)
	Onchorhynchus mykiss, Ictalurus punctatus	Cyanobacteria, actinomycetes	(Robertson et al., 2005)
	Sevielleta LTER, New Mexico, USA	*Leptolyngbya sp.*	(Payne et al., 2001)
Other	MDI liquid medium	Basidiobolus ranarum	(Trowitzsch et al., 1981)
	Laboratory bioreactor	Streptomyces citreus CBS109.60	(Pollak and Berger, 1996)
	Mycelial soil bacteria	Streptomyces coelicolor A3	(Gust et al., 2003)
	Soil	Streptomyces coelicolor A3, Streptomyces avermitilis sp	(Jiang et al., 2007)

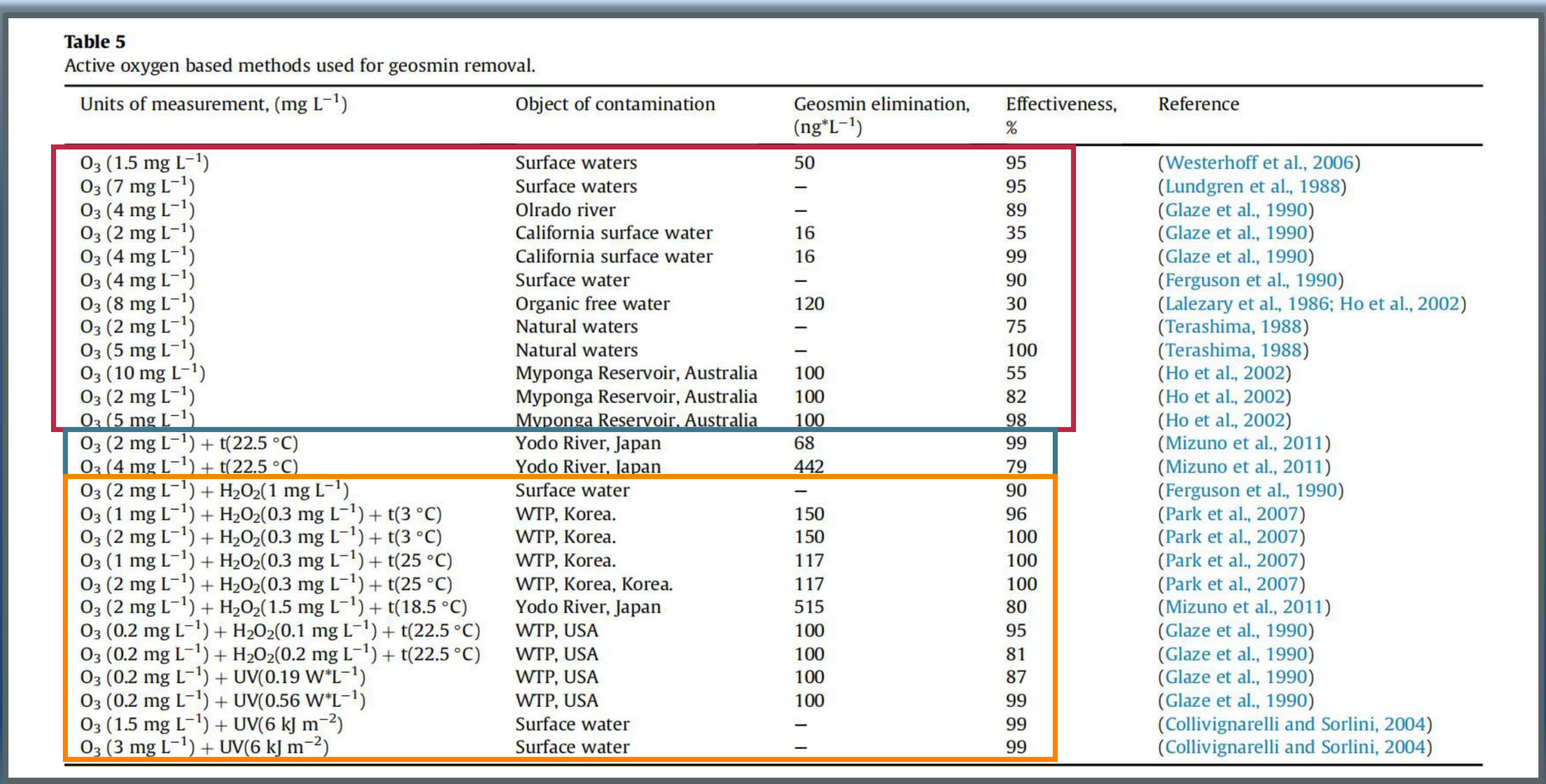


Table 5
Active oxygen based methods used for geosmin removal.

Units of measurement, (mg L^{-1})	Object of contamination	Geosmin elimination, (ng*L^{-1})	Effectiveness, %	Reference
O_3 (1.5 mg L^{-1})	Surface waters	50	95	(Westerhoff et al., 2006)
O_3 (7 mg L^{-1})	Surface waters	–	95	(Lundgren et al., 1988)
O_3 (4 mg L^{-1})	Olrado river	–	89	(Glaze et al., 1990)
O_3 (2 mg L^{-1})	California surface water	16	35	(Glaze et al., 1990)
O_3 (4 mg L^{-1})	California surface water	16	99	(Glaze et al., 1990)
O_3 (4 mg L^{-1})	Surface water	–	90	(Ferguson et al., 1990)
O_3 (8 mg L^{-1})	Organic free water	120	30	(Lalezary et al., 1986; Ho et al., 2002)
O_3 (2 mg L^{-1})	Natural waters	–	75	(Terashima, 1988)
O_3 (5 mg L^{-1})	Natural waters	–	100	(Terashima, 1988)
O_3 (10 mg L^{-1})	Myponga Reservoir, Australia	100	55	(Ho et al., 2002)
O_3 (2 mg L^{-1})	Myponga Reservoir, Australia	100	82	(Ho et al., 2002)
O_3 (5 mg L^{-1})	Myponga Reservoir, Australia	100	98	(Ho et al., 2002)
O_3 (2 mg L^{-1}) + t(22.5 °C)	Yodo River, Japan	68	99	(Mizuno et al., 2011)
O_3 (4 mg L^{-1}) + t(22.5 °C)	Yodo River, Japan	442	79	(Mizuno et al., 2011)
O_3 (2 mg L^{-1}) + H_2O_2(1 mg L^{-1})	Surface water	–	90	(Ferguson et al., 1990)
O_3 (1 mg L^{-1}) + H_2O_2(0.3 mg L^{-1}) + t(3 °C)	WTP, Korea.	150	96	(Park et al., 2007)
O_3 (2 mg L^{-1}) + H_2O_2(0.3 mg L^{-1}) + t(3 °C)	WTP, Korea.	150	100	(Park et al., 2007)
O_3 (1 mg L^{-1}) + H_2O_2(0.3 mg L^{-1}) + t(25 °C)	WTP, Korea.	117	100	(Park et al., 2007)
O_3 (2 mg L^{-1}) + H_2O_2(0.3 mg L^{-1}) + t(25 °C)	WTP, Korea, Korea.	117	100	(Park et al., 2007)
O_3 (2 mg L^{-1}) + H_2O_2(1.5 mg L^{-1}) + t(18.5 °C)	Yodo River, Japan	515	80	(Mizuno et al., 2011)
O_3 (0.2 mg L^{-1}) + H_2O_2(0.1 mg L^{-1}) + t(22.5 °C)	WTP, USA	100	95	(Glaze et al., 1990)
O_3 (0.2 mg L^{-1}) + H_2O_2(0.2 mg L^{-1}) + t(22.5 °C)	WTP, USA	100	81	(Glaze et al., 1990)
O_3 (0.2 mg L^{-1}) + UV(0.19 W*L^{-1})	WTP, USA	100	87	(Glaze et al., 1990)
O_3 (0.2 mg L^{-1}) + UV(0.56 W*L^{-1})	WTP, USA	100	99	(Glaze et al., 1990)
O_3 (1.5 mg L^{-1}) + UV(6 kJ m^{-2})	Surface water	–	99	(Collivignarelli and Sorlini, 2004)
O_3 (3 mg L^{-1}) + UV(6 kJ m^{-2})	Surface water	–	99	(Collivignarelli and Sorlini, 2004)

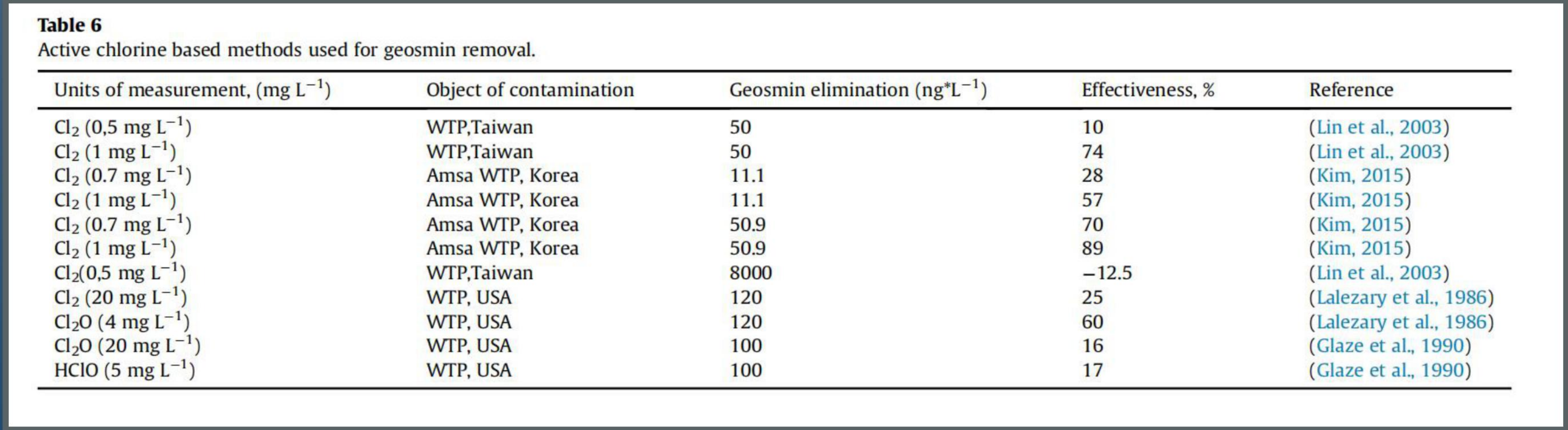


Table 6
Active chlorine based methods used for geosmin removal.

Units of measurement, (mg L^{-1})	Object of contamination	Geosmin elimination (ng*L^{-1})	Effectiveness, %	Reference
Cl_2 (0,5 mg L^{-1})	WTP,Taiwan	50	10	(Lin et al., 2003)
Cl_2 (1 mg L^{-1})	WTP,Taiwan	50	74	(Lin et al., 2003)
Cl_2 (0.7 mg L^{-1})	Amsa WTP, Korea	11.1	28	(Kim, 2015)
Cl_2 (1 mg L^{-1})	Amsa WTP, Korea	11.1	57	(Kim, 2015)
Cl_2 (0.7 mg L^{-1})	Amsa WTP, Korea	50.9	70	(Kim, 2015)
Cl_2 (1 mg L^{-1})	Amsa WTP, Korea	50.9	89	(Kim, 2015)
Cl_2(0,5 mg L^{-1})	WTP,Taiwan	8000	−12.5	(Lin et al., 2003)
Cl_2 (20 mg L^{-1})	WTP, USA	120	25	(Lalezary et al., 1986)
Cl_2O (4 mg L^{-1})	WTP, USA	120	60	(Lalezary et al., 1986)
Cl_2O (20 mg L^{-1})	WTP, USA	100	16	(Glaze et al., 1990)
HClO (5 mg L^{-1})	WTP, USA	100	17	(Glaze et al., 1990)

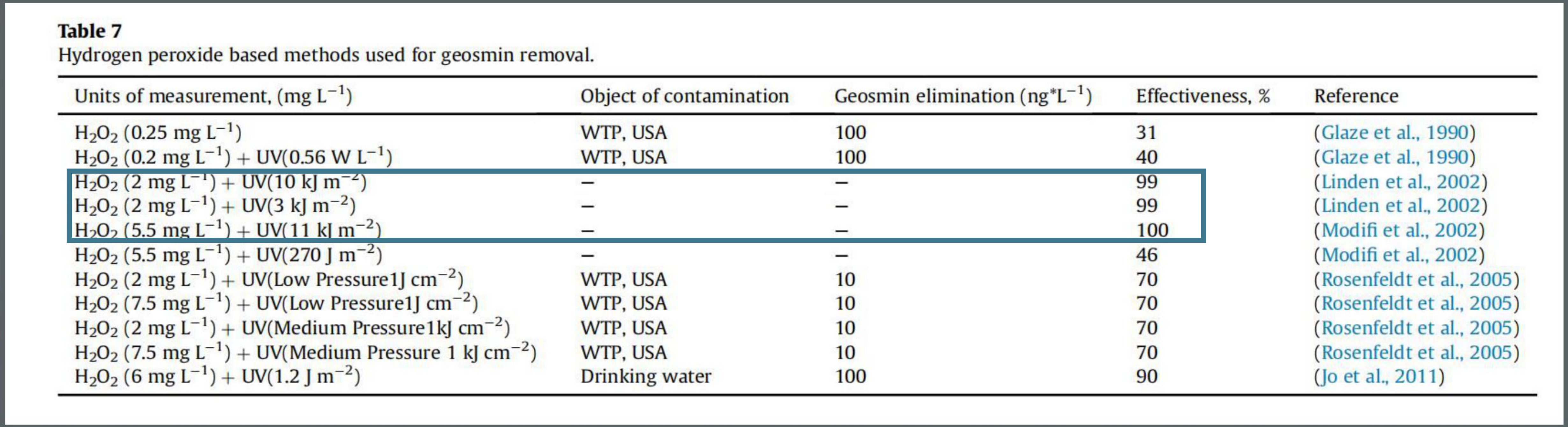


Table 7

Hydrogen peroxide based methods used for geosmin removal.

Units of measurement, (mg L^{-1})	Object of contamination	Geosmin elimination (ng*L^{-1})	Effectiveness, %	Reference
H_2O_2 (0.25 mg L^{-1})	WTP, USA	100	31	(Glaze et al., 1990)
H_2O_2 (0.2 mg L^{-1}) + UV(0.56 W L^{-1})	WTP, USA	100	40	(Glaze et al., 1990)
H_2O_2 (2 mg L^{-1}) + UV(10 kJ m^{-2})	–	–	99	(Linden et al., 2002)
H_2O_2 (2 mg L^{-1}) + UV(3 kJ m^{-2})	–	–	99	(Linden et al., 2002)
H_2O_2 (5.5 mg L^{-1}) + UV(11 kJ m^{-2})	–	–	100	(Modifi et al., 2002)
H_2O_2 (5.5 mg L^{-1}) + UV(270 J m^{-2})	–	–	46	(Modifi et al., 2002)
H_2O_2 (2 mg L^{-1}) + UV(Low Pressure1J cm^{-2})	WTP, USA	10	70	(Rosenfeldt et al., 2005)
H_2O_2 (7.5 mg L^{-1}) + UV(Low Pressure1J cm^{-2})	WTP, USA	10	70	(Rosenfeldt et al., 2005)
H_2O_2 (2 mg L^{-1}) + UV(Medium Pressure1kJ cm^{-2})	WTP, USA	10	70	(Rosenfeldt et al., 2005)
H_2O_2 (7.5 mg L^{-1}) + UV(Medium Pressure 1 kJ cm^{-2})	WTP, USA	10	70	(Rosenfeldt et al., 2005)
H_2O_2 (6 mg L^{-1}) + UV(1.2 J m^{-2})	Drinking water	100	90	(Jo et al., 2011)

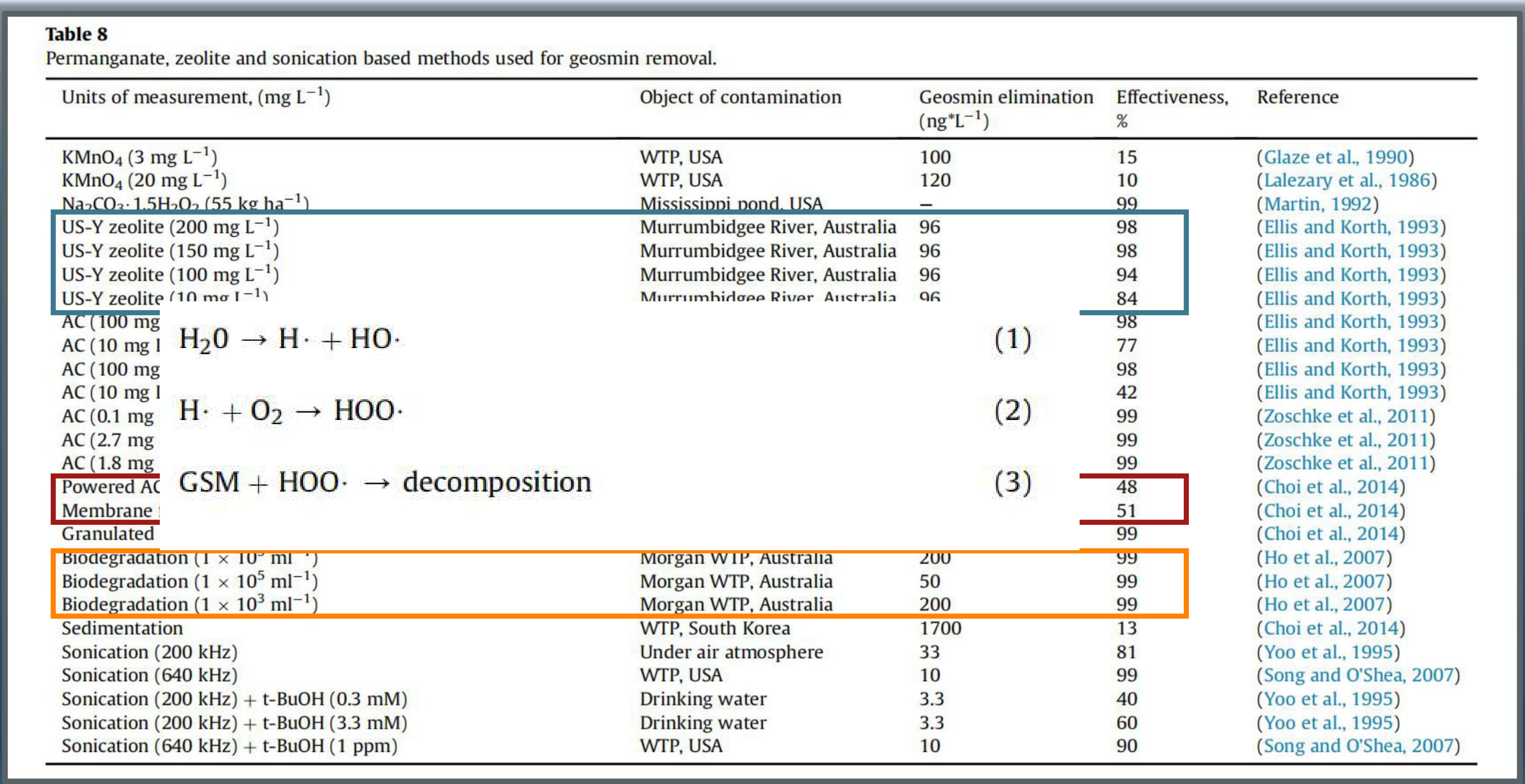


Table 8

Permanganate, zeolite and sonication based methods used for geosmin removal.

Units of measurement, (mg L^{-1})	Object of contamination	Geosmin elimination ($ng*L^{-1}$)	Effectiveness, %	Reference
$KMnO_4$ (3 mg L^{-1})	WTP, USA	100	15	(Glaze et al., 1990)
$KMnO_4$ (20 mg L^{-1})	WTP, USA	120	10	(Lalezary et al., 1986)
$Na_2CO_3 \cdot 1.5H_2O_2$ (55 kg ha^{-1})	Mississippi pond, USA	–	99	(Martin, 1992)
US-Y zeolite (200 mg L^{-1})	Murrumbidgee River, Australia	96	98	(Ellis and Korth, 1993)
US-Y zeolite (150 mg L^{-1})	Murrumbidgee River, Australia	96	98	(Ellis and Korth, 1993)
US-Y zeolite (100 mg L^{-1})	Murrumbidgee River, Australia	96	94	(Ellis and Korth, 1993)
US-Y zeolite (10 mg L^{-1})	Murrumbidgee River, Australia	96	84	(Ellis and Korth, 1993)
AC (100 mg			98	(Ellis and Korth, 1993)
AC (10 mg l			77	(Ellis and Korth, 1993)
AC (100 mg			98	(Ellis and Korth, 1993)
AC (10 mg l			42	(Ellis and Korth, 1993)
AC (0.1 mg			99	(Zoschke et al., 2011)
AC (2.7 mg			99	(Zoschke et al., 2011)
AC (1.8 mg			99	(Zoschke et al., 2011)
Powered AC			48	(Choi et al., 2014)
Membrane			51	(Choi et al., 2014)
Granulated			99	(Choi et al., 2014)
Biodegradation (1 × 10^5 ml^{-1})	Morgan WTP, Australia	200	99	(Ho et al., 2007)
Biodegradation (1 × 10^5 ml^{-1})	Morgan WTP, Australia	50	99	(Ho et al., 2007)
Biodegradation (1 × 10^3 ml^{-1})	Morgan WTP, Australia	200	99	(Ho et al., 2007)
Sedimentation	WTP, South Korea	1700	13	(Choi et al., 2014)
Sonication (200 kHz)	Under air atmosphere	33	81	(Yoo et al., 1995)
Sonication (640 kHz)	WTP, USA	10	99	(Song and O'Shea, 2007)
Sonication (200 kHz) + t-BuOH (0.3 mM)	Drinking water	3.3	40	(Yoo et al., 1995)
Sonication (200 kHz) + t-BuOH (3.3 mM)	Drinking water	3.3	60	(Yoo et al., 1995)
Sonication (640 kHz) + t-BuOH (1 ppm)	WTP, USA	10	90	(Song and O'Shea, 2007)

$$H_20 \rightarrow H\cdot + HO\cdot \qquad (1)$$

$$H\cdot + O_2 \rightarrow HOO\cdot \qquad (2)$$

$$GSM + HOO\cdot \rightarrow \text{decomposition} \qquad (3)$$

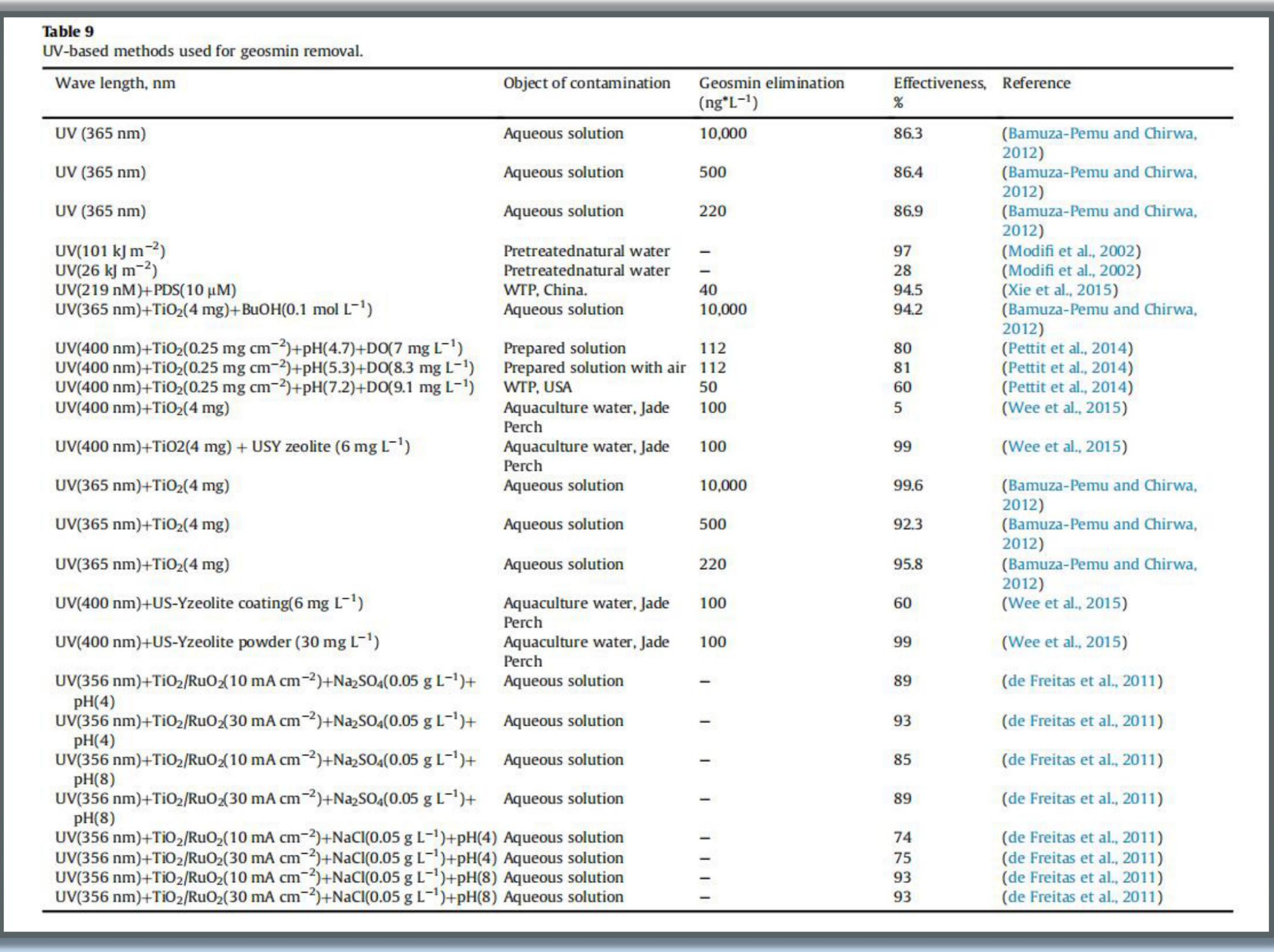


Table 9
UV-based methods used for geosmin removal.

Wave length, nm	Object of contamination	Geosmin elimination ($ng^{*}L^{-1}$)	Effectiveness, %	Reference
UV (365 nm)	Aqueous solution	10,000	86.3	(Bamuza-Pemu and Chirwa, 2012)
UV (365 nm)	Aqueous solution	500	86.4	(Bamuza-Pemu and Chirwa, 2012)
UV (365 nm)	Aqueous solution	220	86.9	(Bamuza-Pemu and Chirwa, 2012)
UV(101 kJ m^{-2})	Pretreatednatural water	–	97	(Modifi et al., 2002)
UV(26 kJ m^{-2})	Pretreatednatural water	–	28	(Modifi et al., 2002)
UV(219 nM)+PDS(10 μM)	WTP, China.	40	94.5	(Xie et al., 2015)
UV(365 nm)+TiO_2(4 mg)+BuOH(0.1 mol L^{-1})	Aqueous solution	10,000	94.2	(Bamuza-Pemu and Chirwa, 2012)
UV(400 nm)+TiO_2(0.25 mg cm^{-2})+pH(4.7)+DO(7 mg L^{-1})	Prepared solution	112	80	(Pettit et al., 2014)
UV(400 nm)+TiO_2(0.25 mg cm^{-2})+pH(5.3)+DO(8.3 mg L^{-1})	Prepared solution with air	112	81	(Pettit et al., 2014)
UV(400 nm)+TiO_2(0.25 mg cm^{-2})+pH(7.2)+DO(9.1 mg L^{-1})	WTP, USA	50	60	(Pettit et al., 2014)
UV(400 nm)+TiO_2(4 mg)	Aquaculture water, Jade Perch	100	5	(Wee et al., 2015)
UV(400 nm)+TiO2(4 mg) + USY zeolite (6 mg L^{-1})	Aquaculture water, Jade Perch	100	99	(Wee et al., 2015)
UV(365 nm)+TiO_2(4 mg)	Aqueous solution	10,000	99.6	(Bamuza-Pemu and Chirwa, 2012)
UV(365 nm)+TiO_2(4 mg)	Aqueous solution	500	92.3	(Bamuza-Pemu and Chirwa, 2012)
UV(365 nm)+TiO_2(4 mg)	Aqueous solution	220	95.8	(Bamuza-Pemu and Chirwa, 2012)
UV(400 nm)+US-Yzeolite coating(6 mg L^{-1})	Aquaculture water, Jade Perch	100	60	(Wee et al., 2015)
UV(400 nm)+US-Yzeolite powder (30 mg L^{-1})	Aquaculture water, Jade Perch	100	99	(Wee et al., 2015)
UV(356 nm)+TiO_2/RuO_2(10 mA cm^{-2})+Na_2SO_4(0.05 g L^{-1})+ pH(4)	Aqueous solution	–	89	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(30 mA cm^{-2})+Na_2SO_4(0.05 g L^{-1})+ pH(4)	Aqueous solution	–	93	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(10 mA cm^{-2})+Na_2SO_4(0.05 g L^{-1})+ pH(8)	Aqueous solution	–	85	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(30 mA cm^{-2})+Na_2SO_4(0.05 g L^{-1})+ pH(8)	Aqueous solution	–	89	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(10 mA cm^{-2})+NaCl(0.05 g L^{-1})+pH(4)	Aqueous solution	–	74	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(30 mA cm^{-2})+NaCl(0.05 g L^{-1})+pH(4)	Aqueous solution	–	75	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(10 mA cm^{-2})+NaCl(0.05 g L^{-1})+pH(8)	Aqueous solution	–	93	(de Freitas et al., 2011)
UV(356 nm)+TiO_2/RuO_2(30 mA cm^{-2})+NaCl(0.05 g L^{-1})+pH(8)	Aqueous solution	–	93	(de Freitas et al., 2011)

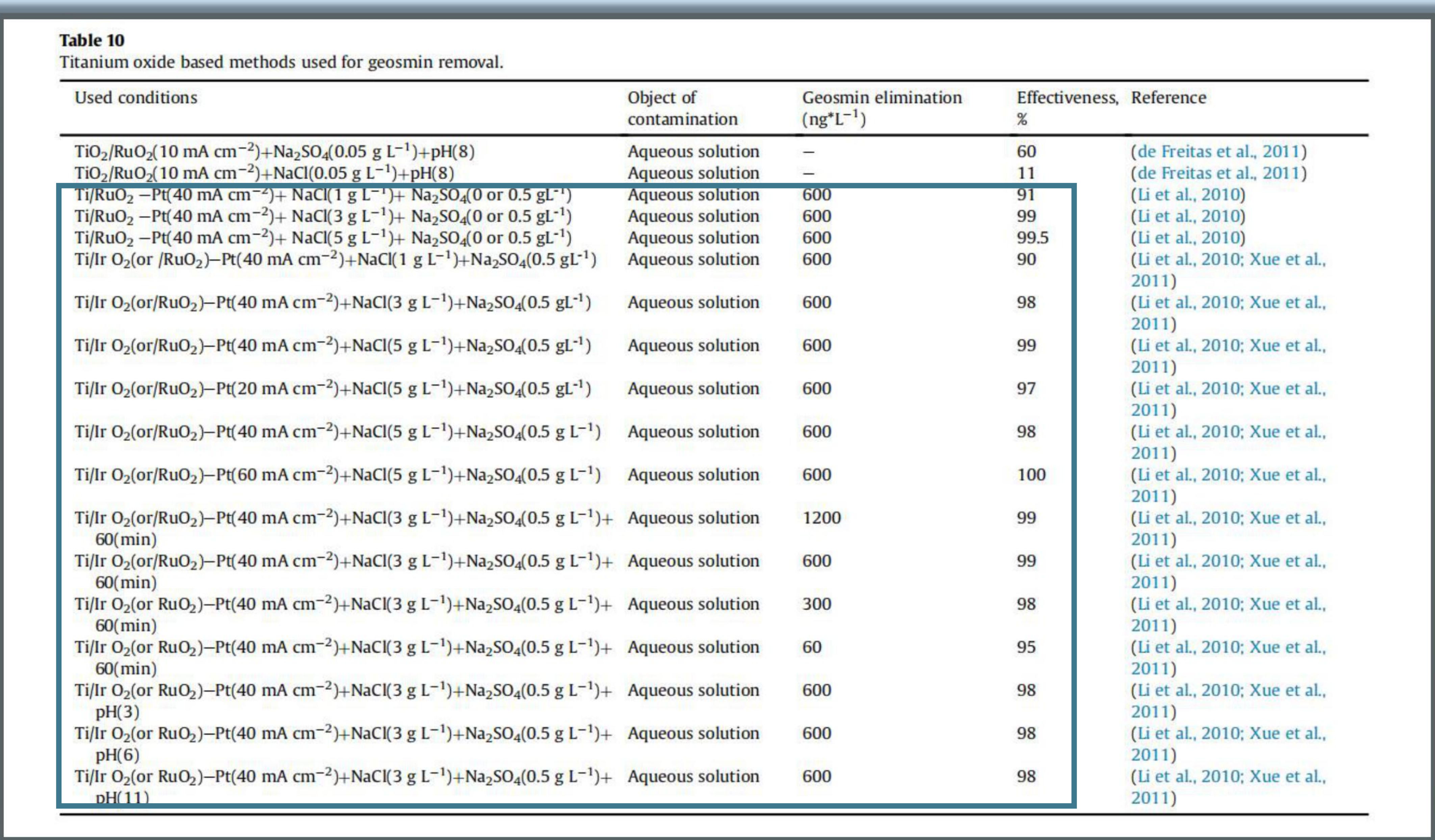


Table 10
Titanium oxide based methods used for geosmin removal.

Used conditions	Object of contamination	Geosmin elimination ($ng*L^{-1}$)	Effectiveness, %	Reference
TiO_2/RuO_2(10 mA cm^{-2})+Na_2SO_4(0.05 g L^{-1})+pH(8)	Aqueous solution	–	60	(de Freitas et al., 2011)
TiO_2/RuO_2(10 mA cm^{-2})+NaCl(0.05 g L^{-1})+pH(8)	Aqueous solution	–	11	(de Freitas et al., 2011)
Ti/RuO_2 –Pt(40 mA cm^{-2})+ NaCl(1 g L^{-1})+ Na_2SO_4(0 or 0.5 gL^{-1})	Aqueous solution	600	91	(Li et al., 2010)
Ti/RuO_2 –Pt(40 mA cm^{-2})+ NaCl(3 g L^{-1})+ Na_2SO_4(0 or 0.5 gL^{-1})	Aqueous solution	600	99	(Li et al., 2010)
Ti/RuO_2 –Pt(40 mA cm^{-2})+ NaCl(5 g L^{-1})+ Na_2SO_4(0 or 0.5 gL^{-1})	Aqueous solution	600	99.5	(Li et al., 2010)
Ti/Ir O_2(or /RuO_2)–Pt(40 mA cm^{-2})+NaCl(1 g L^{-1})+Na_2SO_4(0.5 gL^{-1})	Aqueous solution	600	90	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 gL^{-1})	Aqueous solution	600	98	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(40 mA cm^{-2})+NaCl(5 g L^{-1})+Na_2SO_4(0.5 gL^{-1})	Aqueous solution	600	99	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(20 mA cm^{-2})+NaCl(5 g L^{-1})+Na_2SO_4(0.5 gL^{-1})	Aqueous solution	600	97	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(40 mA cm^{-2})+NaCl(5 g L^{-1})+Na_2SO_4(0.5 g L^{-1})	Aqueous solution	600	98	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(60 mA cm^{-2})+NaCl(5 g L^{-1})+Na_2SO_4(0.5 g L^{-1})	Aqueous solution	600	100	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ 60(min)	Aqueous solution	1200	99	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or/RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ 60(min)	Aqueous solution	600	99	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ 60(min)	Aqueous solution	300	98	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ 60(min)	Aqueous solution	60	95	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ pH(3)	Aqueous solution	600	98	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ pH(6)	Aqueous solution	600	98	(Li et al., 2010; Xue et al., 2011)
Ti/Ir O_2(or RuO_2)–Pt(40 mA cm^{-2})+NaCl(3 g L^{-1})+Na_2SO_4(0.5 g L^{-1})+ pH(11)	Aqueous solution	600	98	(Li et al., 2010; Xue et al., 2011)

UV 提供水的

（BrO3）

该方法包括应用Ti涂覆的电极（阳极）和IrO2 并掺杂Pt（Ti/IrO2 -Pt）。
阳极有机物电化学降解的机理主要是通过阳极催化水电解产生吸附的羟基自由基。
羟基自由基彼此反应将形成氧分子。

$$H_2O + MO_x \rightarrow MO_x[\cdot OH] + H^+ + e$$

$$MO_x[\cdot OH] \rightarrow MO_{x+1} + H^+ + e$$

$$MO_x[\cdot OH] \rightarrow M + O_2 + H^+ + e$$

生产其他强氧化剂

$$H_2O + Cl^- \rightarrow HOCl + H^+ + 2e^-$$

有机物质（R）的氧化可以由羟基自由基诱导

$$R + MO_x[\cdot OH] \rightarrow MO_x + CO_2 + zH^+ + ze^-$$

$$MO_{x+1} + R \rightarrow MO_x + RO$$

$$R + HOCl \rightarrow \text{产物} + Cl^-$$

4

TITLE

结果与讨论

- 对土臭素污染产品的排斥是食品和水处理行业的重要问题

- 通路形成的多样性以及产生土臭素分子的微生物的多样性促使我们需要找到简单易行的稳定高效的去除方法

- 不同处理的组合比单独一种处理更有效

- 从经济观点和过程操作来看，土臭素的氧化途径是更合适的途径。

- 有效性氧化剂：ClO2>O3>MnO2（s）>Cl2> KMnO4

- 诸如TiO2的催化剂的应用以及UV辐射或超声处理增加了清除的功效。

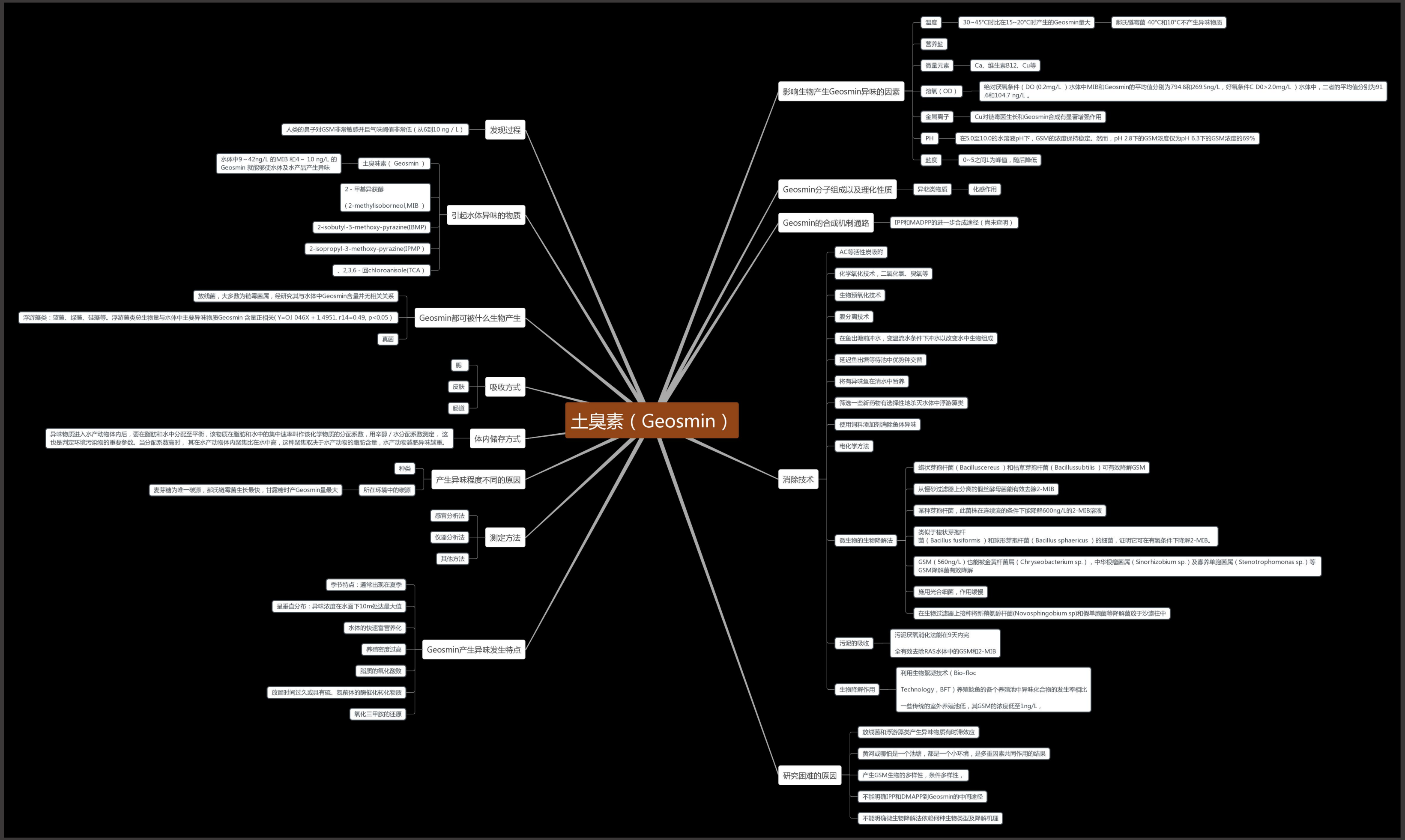
- 电化学降解成功地证明了其去除土臭味素的高效并且不需要太多的经济和技术设备。

5

TITLE

个人总结分享

自我总结之后，发现诸如Geosmin等物质可以由几大类表述。我将其制成一张表以供大家更为清晰的了解土臭素。



- 土臭素（Geosmin）
  - 影响生物产生Geosmin异味的因素
    - 温度
      - 30~45°C时比在15~20°C时产生的Geosmin量大
        - 郝氏链霉菌 40°C和10°C不产生异味物质
    - 营养盐
    - 微量元素
      - Ca、维生素B12、Cu等
    - 溶氧（OD）
      - 绝对厌氧条件（DO (0.2mg/L ）水体中MIB和Geosmin的平均值分别为794.8和269.Sng/L，好氧条件C D0>2.0mg/L ）水体中，二者的平均值分别为91.6和104.7 ng/L 。
    - 金属离子
      - Cu对链霉菌生长和Geosmin合成有显著增强作用
    - PH
      - 在5.0至10.0的水溶液pH下，GSM的浓度保持稳定。然而，pH 2.8下的GSM浓度仅为pH 6.3下的GSM浓度的69%
    - 盐度
      - 0~5之间1为峰值，随后降低
  - Geosmin分子组成以及理化性质
    - 异萜类物质
      - 化感作用
  - Geosmin的合成机制通路
    - IPP和MADPP的进一步合成途径（尚未查明）
  - 消除技术
    - AC等活性炭吸附
    - 化学氧化技术，二氧化氯、臭氧等
    - 生物预氧化技术
    - 膜分离技术
    - 在鱼出塘前冲水，变温流水条件下冲水以改变水中生物组成
    - 延迟鱼出塘等待池中优势种交替
    - 将有异味鱼在清水中暂养
    - 筛选一些新药物有选择性地杀灭水体中浮游藻类
    - 使用饲料添加剂消除鱼体异味
    - 电化学方法
    - 微生物的生物降解法
      - 蜡状芽孢杆菌（Bacilluscereus ）和枯草芽孢杆菌（Bacillussubtilis ）可有效降解GSM
      - 从慢砂过滤器上分离的假丝酵母菌能有效去除2-MIB
      - 某种芽孢杆菌，此菌株在连续流的条件下能降解600ng/L的2-MIB溶液
      - 类似于梭状芽孢杆菌（Bacillus fusiformis ）和球形芽孢杆菌（Bacillus sphaericus ）的细菌，证明它可在有氧条件下降解2-MIB。
      - GSM（560ng/L）也能被金黄杆菌属（Chryseobacterium sp.），中华根瘤菌属（Sinorhizobium sp.）及寡养单胞菌属（Stenotrophomonas sp.）等GSM降解菌有效降解
      - 施用光合细菌，作用缓慢
      - 在生物过滤器上接种将新鞘氨醇杆菌(Novosphingobium sp)和假单胞菌等降解菌放于沙滤柱中
    - 污泥的吸收
      - 污泥厌氧消化法能在9天内完全有效去除RAS水体中的GSM和2-MIB
    - 生物降解作用
      - 利用生物絮凝技术（Bio-floc Technology，BFT）养殖鲶鱼的各个养殖池中异味化合物的发生率相比一些传统的室外养殖池低，其GSM的浓度低至1ng/L，
  - 研究困难的原因
    - 放线菌和浮游藻类产生异味物质有时滞效应
    - 黄河或哪怕是一个池塘，都是一个小环境，是多重因素共同作用的结果
    - 产生GSM生物的多样性，条件多样性，
    - 不能明确IPP和DMAPP到Geosmin的中间途径
    - 不能明确微生物降解法依赖何种生物类型及降解机理
  - 发现过程
    - 人类的鼻子对GSM非常敏感并且气味阈值非常低（从6到10 ng / L）
  - 引起水体异味的物质
    - 土臭味素（ Geosmin ）
      - 水体中9～42ng/L 的MIB 和4～ 10 ng/L 的Geosmin 就能够使水体及水产品产生异味
    - 2 - 甲基异莰醇（2-methylisoborneol,MIB ）
    - 2-isobutyl-3-methoxy-pyrazine(IBMP)
    - 2-isopropyl-3-methoxy-pyrazine(IPMP)
    - 、2,3,6 - 回chloroanisole(TCA)
  - Geosmin都可被什么生物产生
    - 放线菌，大多数为链霉菌属，经研究其与水体中Geosmin含量并无相关关系
    - 浮游藻类：蓝藻、绿藻、硅藻等。浮游藻类总生物量与水体中主要异味物质Geosmin 含量正相关(Y=O.l 046X + 1.4951. r14=0.49, p<0.05)
    - 真菌
  - 吸收方式
    - 腮
    - 皮肤
    - 肠道
  - 体内储存方式
    - 异味物质进入水产动物体内后，要在脂肪和水中分配至平衡，该物质在脂肪和水中的集中速率叫作该化学物质的分配系数，用辛醇 / 水分配系数测定， 这也是判定环境污染物的重要参数。当分配系数高时， 其在水产动物体内聚集比在水中高，这种聚集取决于水产动物的脂肪含量，水产动物越肥异味越重。
  - 产生异味程度不同的原因
    - 种类
    - 所在环境中的碳源
      - 麦芽糖为唯一碳源，郝氏链霉菌生长最快，甘露糖时产Geosmin量最大
  - 测定方法
    - 感官分析法
    - 仪器分析法
    - 其他方法
  - Geosmin产生异味发生特点
    - 季节特点：通常出现在夏季
    - 呈垂直分布：异味浓度在水面下10m处达最大值
    - 水体的快速富营养化
    - 养殖密度过高
    - 脂质的氧化酸败
    - 放置时间过久或具有硫、氮前体的酶催化转化物质
    - 氧化三甲胺的还原

感谢各位的聆听

请各位老师、同学批评指正