

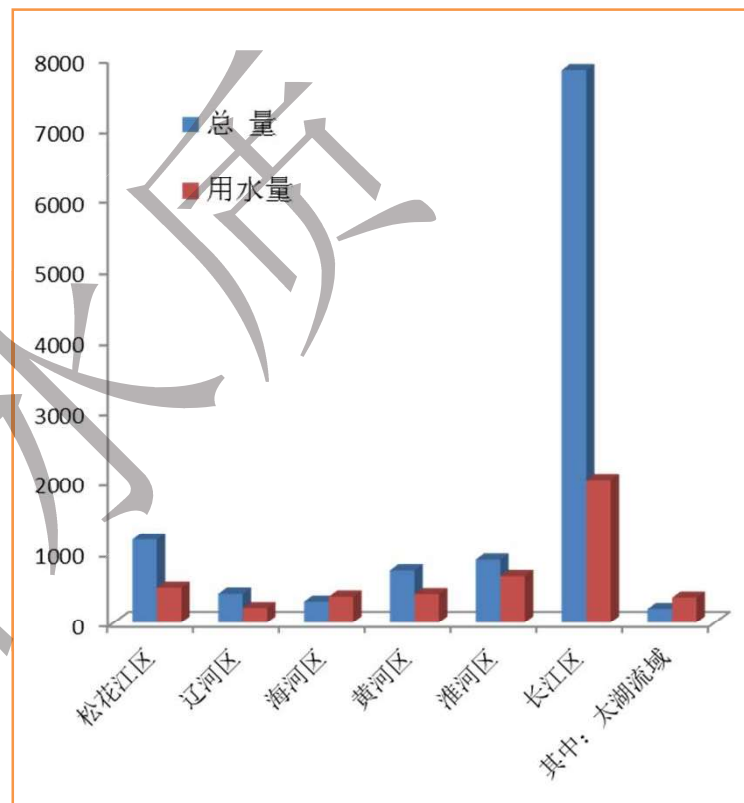
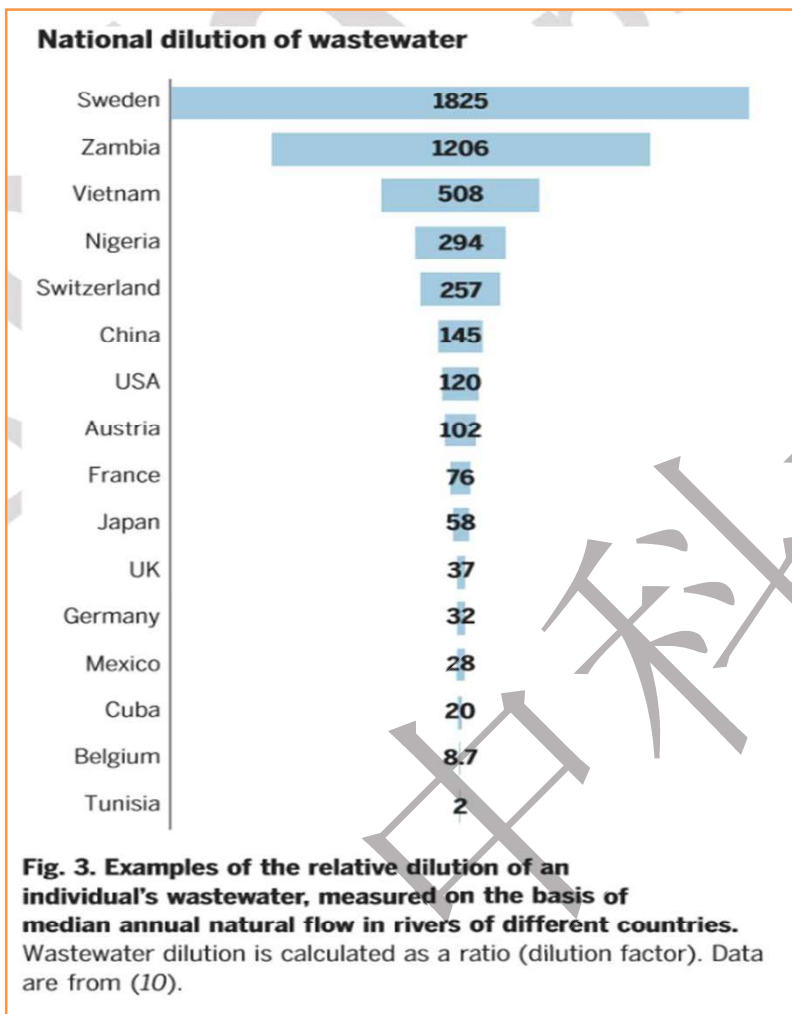
日、美、欧富营养化控制及其营养盐水质标准

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全球主要国家和中国排放标准达水质标准中的难点分析(环境容量概念)



通过稀释作用达标的潜力分析:

- ◆ 完全没有稀释能力: 海河、太湖
- ◆ 具有部分稀释能力: 辽河、黄河、淮河
- ◆ 相对充足稀释能力: 长江、珠江等

中国水质达标的保证方式: 排放量 > 环境容量(稀释容量) = 总量控制 + 地方标准

日本的水质相关的标准及富营养化控制实践

日本水污染控制的法规体系：水质保障三项措施

- 1. 排放标准:**1970年日本《水污染控制法》第二章第三条是有关污水排放标准的规定，包含有**常规污染物、特征污染物和有害物质**。排放标准对每个有害物质规定了**最大允许排放水平**。而对其他种类的污染物，法规规定应当按照允许的最高限量制定排放标准。排放标准适用于大多数类型的水体。
- 2. 总量控制:**1978年提出的总量控制是在**仅通过排放标准无法达到环境质量要求**前提下实施的政策，适用生活和工业部门排放大量污水的大型封闭公共水体。
- 3. 环境质量标准:**1993年修订的《基本环境法》确定了有关环境保护的基本国策，其中引入了环境质量标准(EQS)概念。水质标准划分为**保护人体健康和保护生活环境**的两类环境水质标准，并对每一项指标都规定了实现和维持公共水体期望达到的水质目标和满足其他水质政策目标的具体要求。

- 1978年《水污染控制法》修正案第二章的4-2条款包含一个总量控制概念：在降低总污染负荷的基本政策框架内，在规定的年限内进一步降低排放量并采取其他基本措施减少点源总污染物负荷(**目标总量**)。
- 水污染防治、水质管理、工业排放和分散污水处理(净化槽)归环境部，水资源管理和市镇污水归属通产省，海洋和地下水污染由环境部和通产省共同管理。

日本全国统一的污水和废水排放标准(排放标准仅针对指定实施)

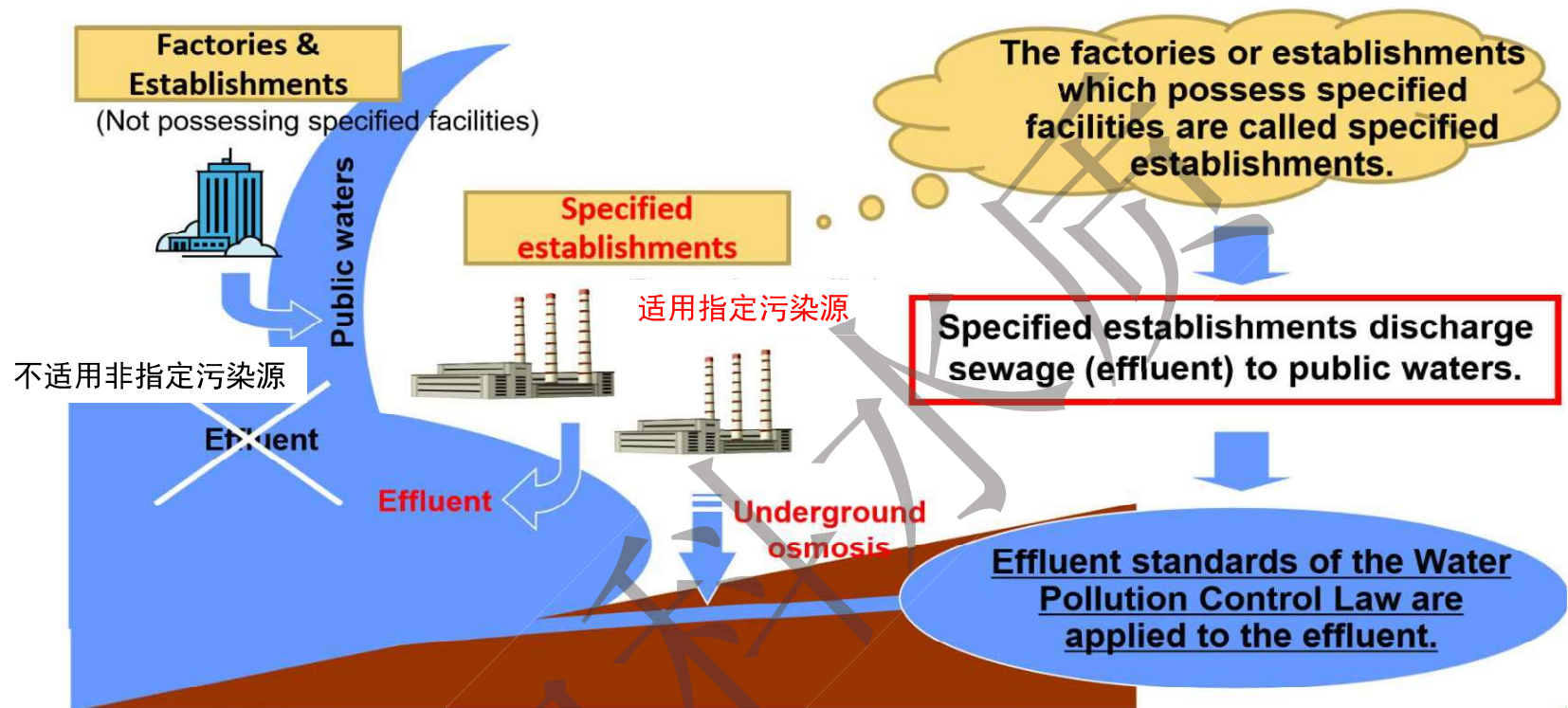
保护人体健康的排放标准

保护生活环境的排放标准

Potential Hydrogen (pH)	Non-coastal areas : Coastal areas :	5.8-8.6 5.0-9.0
Biochemical Oxygen Demand (BOD)		160 mg/l (Daily Average 120 mg/l)
Chemical Oxygen Demand (COD)		160 mg/l (Daily Average 120 mg/l)
Suspended solids (SS)		200 mg/l (Daily Average 150 mg/l)
N-hexane Extracts (mineral oil)		5 mg/l
<ul style="list-style-type: none"> • BOD指标适用于排放进入河流; • COD指标适用于排放进入海、湖; • 总氮、总磷适用于指定的(潜在富营养化)湖泊或(潜在富营养化)海域; • 执行总氮和总磷排放标准的水域分别由环境部N27号令(1985)和67号令(1993)界定。 		
Chromium		2 mg/l
Coliform groups		Daily Average 3000/cm ³
Nitrogen		120 mg/l (Daily Average 60 mg/l)
Phosphorus		16 mg/l (Daily Average 8 mg/l)

Cadmium and its compounds		0.03 mg Cd/l
Cyanide compounds		1 mg CN/l
Organic phosphorus compounds (Parathion, Methyl Parathion, Methyl Demeton and EPN only)		1 mg/l
Lead and its compounds		0.1 mg Pb/l
Hexavalent Chromium		0.5 mg Cr(VI)/l
Arsenic and its compounds		0.1 mg As/l
Mercury and its compounds		0.005 mg Hg/l
Alkyl mercury compounds		Not detectable
PCBs		0.003 mg/l
Trichloroethylene		0.1 mg/l
Tetrachloroethylene		0.1 mg/l
Dichloromethane		0.2 mg/l
Carbon Tetrachloride		0.02 mg/l
1, 2-Dichloro ethane		0.04 mg/l
1, 1-Dichloro ethylene		1 mg/l
cis-1, 2-Dichloro ethylene		0.4 mg/l
1, 1, 1-Trichloro ethane		3 mg/l
1, 1, 2-Trichloro ethane		0.06 mg/l
1, 3-Dichloropropene		0.02 mg/l
Thiram		0.06 mg/l
Simazine		0.03 mg/l
Thiobencarb		0.2 mg/l
Benzene		0.1 mg/l
Selenium and its compounds		0.1 mg Se/l
Boron and its compounds	Non-coastal areas : Coastal areas :	10 mg B/l 230 mg B/l
Fluorine and its compounds	Non-coastal areas : Coastal areas :	8 mg F/l 15 mg F/l
Ammonia, Ammonium compounds, Nitrate and Nitrite compounds	Total of NH ₃ -N multiplied by 0.4, NO ₂ -N and NO ₃ -N:	100 mg/l
1,4-Dioxane		0.5mg/l

日本排放标准针对的指定工厂(FACTORIES)或实施(ESTABLISHMENTS)



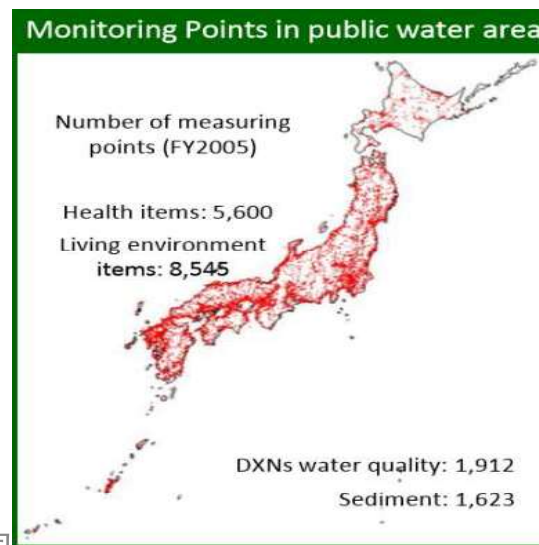
		2006	2007	2008	2009	2010
指定污染源的数目(依据WPCL中的排放标准)		289,091	280,517	276,952	274,039	271,242
average effluent more than 50m ³ /day		36,139	35,506	34,807	34,271	33,964
Notification	Article 5 (Establishment of Specified facilities)	6,279	6,670	6,174	5,075	5,307
	Article 7 (Structure changes etc.)	3,963	3,986	3,841	3,530	3,539
	Article 8 (Order to change plans)	0	0	0	0	0
监督污染源的数目(依据WPCL的22.1)		46,764	47,410	43,509	42,367	41,260
inspection during night		768	686	575	581	588

日本保护生活环境的水质标准(基本环境法)

Living environment items	River	Lake	Sea Area
BOD	≤ 1 - 10 mg/L	-	-
COD	-	≤ 1 - 8 mg/L	≤ 2 - 8 mg/L
pH	6.0 - 8.5	6.0 - 8.5	7.0 - 8.3
SS	≤ 25 - 100 mg/L etc.	≤ 1 - 15 mg/L etc.	-
DO	2-7.5 mg/L ≤	2-7.5 mg/L ≤	2-7.5 mg/L ≤
Coliform bacteria count	≤ 50 - 5,000 MPN/100 mL	≤ 50 - 1,000 MPN/100 mL	≤ 1,000 MPN/100 mL
N-hexane extracts	-	-	Undetected.
Total nitrogen	-	≤ 0.1 - 1 mg/L	≤ 0.2 - 1 mg/L
Total phosphorous	-	≤ 0.005 - 0.1 mg/L	≤ 0.02 - 0.09 mg/L
All zinc	≤ 0.03 mg/L	≤ 0.03 mg/L	≤ 0.01 - 0.02 mg/L

- BOD₅标准适用于除海、湖以外公共水域；
- COD_{Mn}指标适用于海、湖水域；
- 总氮、总磷仅适用于指定的湖、海水域；
- 保护生活环境的水质标准分类分级。

保护健康的水质监测点： 5600
 保护生活环境的监测点： 8545
 DXNs水质监测点： 1912
 沉积物质量监测点： 1623



日本保护生活环境标准的案例分析(EQS-CLE)

河流

Item class	Water use	Standard value				
		Hydrogen-ion concentration (pH)	Biochemical oxygen demand (BOD)	Suspended solids (SS)	Dissolved oxygen (DO)	Total coliform
AA	Water supply class 1, conservation of natural environment, and uses listed in A-E	$6.5 \leq \text{pH} \leq 8.5$	$\leq 1 \text{ mg/L}$	$\leq 25 \text{ mg/L}$	$\geq 7.5 \text{ mg/L}$	$\leq 50 \text{ MPN/100mL}$
A	Water supply class 2, fishery class 1, bathing and uses listed in B-E	$6.5 \leq \text{pH} \leq 8.5$	$\leq 2 \text{ mg/L}$	$\leq 25 \text{ mg/L}$	$\geq 7.5 \text{ mg/L}$	$\leq 1,000 \text{ MPN/100mL}$
B	Water supply class 3, fishery class 2, and uses listed in C-E	$6.5 \leq \text{pH} \leq 8.5$	$\leq 3 \text{ mg/L}$	$\leq 25 \text{ mg/L}$	$\geq 5 \text{ mg/L}$	$\leq 5,000 \text{ MPN/100mL}$
C	Fishery class 3, industrial water class 1, and uses listed in D-E	$6.5 \leq \text{pH} \leq 8.5$	$\leq 5 \text{ mg/L}$	$\leq 50 \text{ mg/L}$	$\geq 5 \text{ mg/L}$	—
D	Industrial water class 2, agricultural water, and uses listed in E	$6.0 \leq \text{pH} \leq 8.5$	$\leq 8 \text{ mg/L}$	$\leq 100 \text{ mg/L}$	$\geq 2 \text{ mg/L}$	—
E	Industry water class 3 and conservation of environment	$6.0 \leq \text{pH} \leq 8.5$	$\leq 10 \text{ mg/L}$	Floating matter such as garbage should not be observed.	$\geq 2 \text{ mg/L}$	—

湖库湾

Item class	Water use	Standard value	
		Total nitrogen	Total phosphorus
I	Conservation of natural environment and uses listed in II-V	$\leq 0.1 \text{ mg/L}$	$\leq 0.005 \text{ mg/L}$
II	Water supply classes 1, 2, and 3 (except special types), fishery class 1, bathing, and uses listed in III-V	$\leq 0.2 \text{ mg/L}$	$\leq 0.01 \text{ mg/L}$
III	Water supply class 3 (special types) and uses listed in IV-V	$\leq 0.4 \text{ mg/L}$	$\leq 0.03 \text{ mg/L}$
IV	Fishery class 2 and uses listed in V	$\leq 0.6 \text{ mg/L}$	$\leq 0.05 \text{ mg/L}$
V	Fishery class 3, industrial water, agricultural water, and conservation of the environment	$\leq 1 \text{ mg/L}$	$\leq 0.1 \text{ mg/L}$

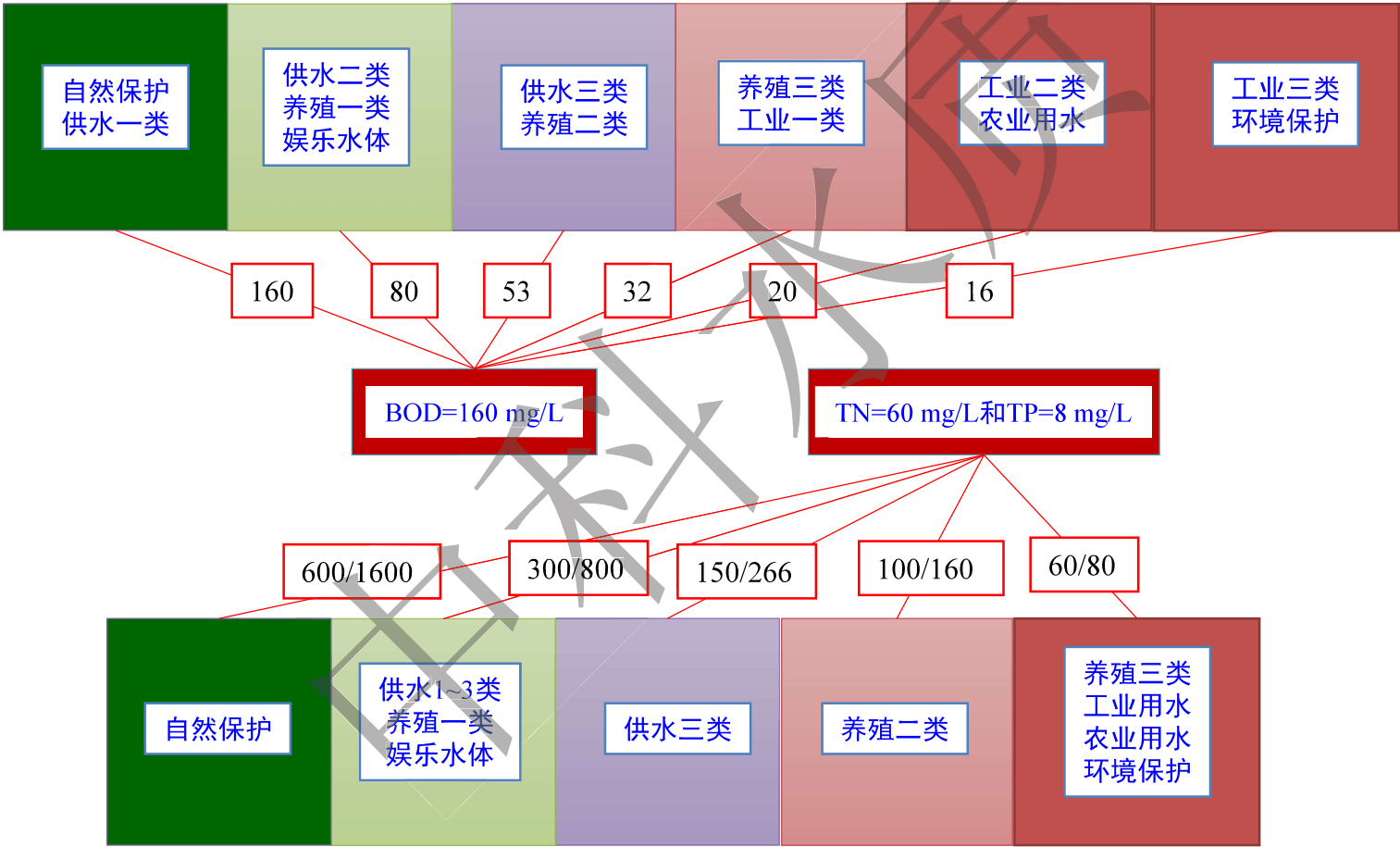
生境-锌

Item class	Adaptability of the habitat status of aquatic life	Standard value
		Total zinc
Class A organisms	Water areas inhabited by aquatic life	$\leq 0.02 \text{ mg/L}$
Special class A organisms	Of the water areas inhabited by Class A organisms, those that should be conserved as spawning/rearing areas of aquatic life	$\leq 0.01 \text{ mg/L}$

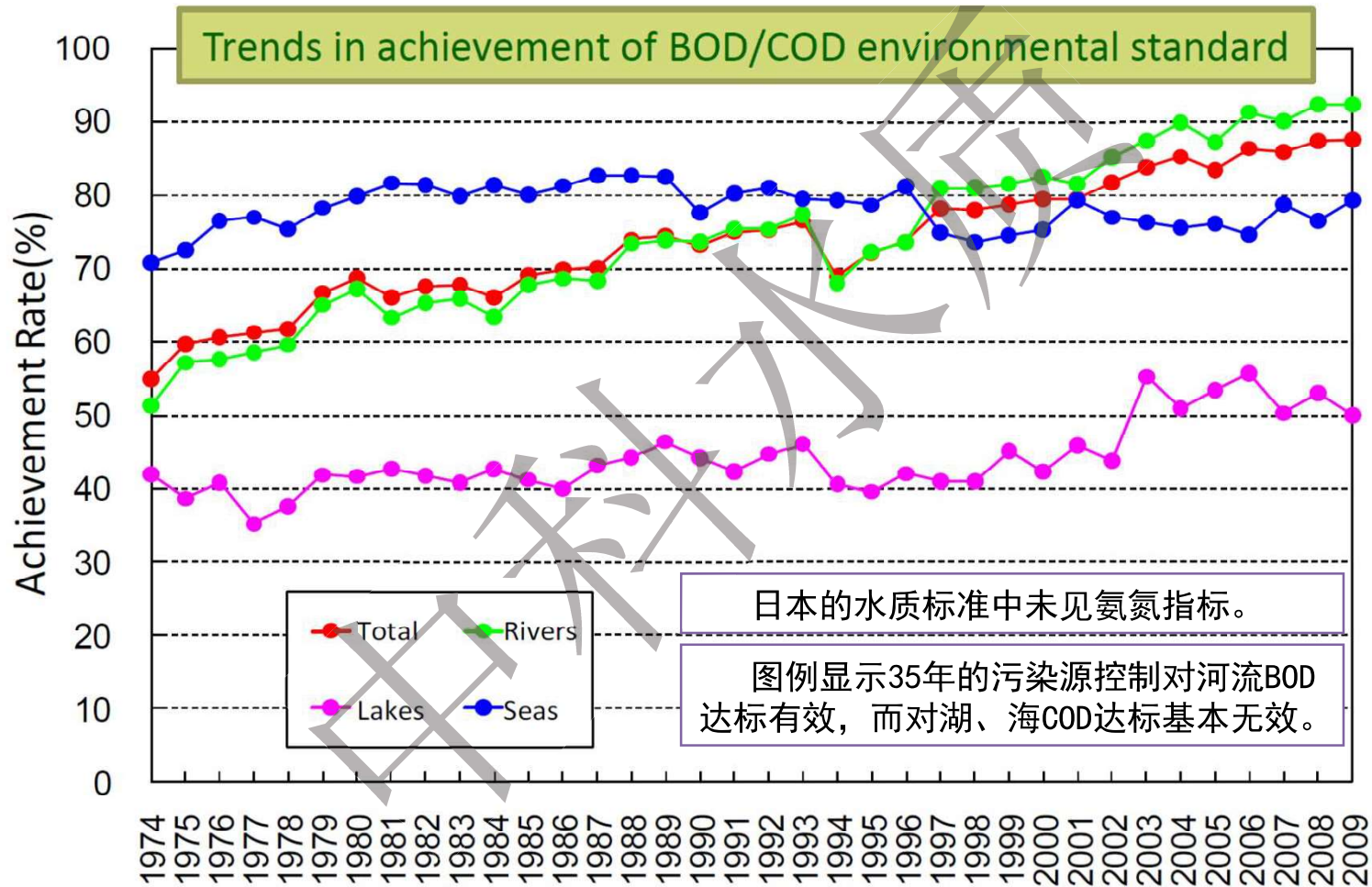
- 生活环境用水水质标准按照功能分区相应的保护对象或处理工艺进一步分级。

日本保护生活环境标准达标所需要的稀释倍数

河流水质标准(BOD)



日本保护生活环境的水质标准中COD/BOD达标率分析



日本的总量控制系统



Total Pollutant Load Control System

Objective:

To reduce the total amount of t
in order to improve the water q

总量控制实施区域：东京湾、
伊势湾和濑户内海。控制指
标包括COD,TN和TP

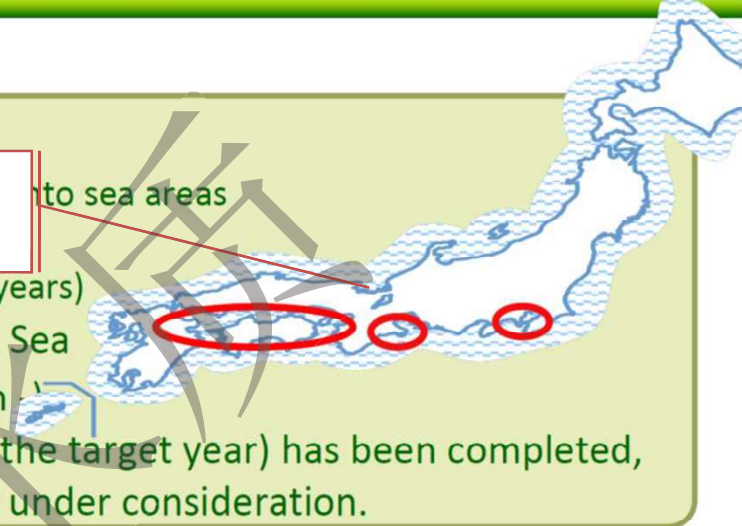
(Tokyo Bay, Ise Bay & Seto Inland Sea) for a set period (5 years)

Object sea areas: Tokyo Bay, Ise Bay & Seto Inland Sea

Object item: COD (1st -), nitrogen, phosphorus (5th

The 6th Total Pollutant Load Control (with Y2011 as the target year) has been completed, and the 7th Total Pollutant Load Control is currently under consideration.

to sea areas



Basic Policy for Total Load Reduction

The Minister of the Environment determines the five year reduction goal for each target area



执行方式：根据污染源类别和减
量要求确定总量目标

Plan for Total Load Reduction

plan for the target amount of reduction according to source categories and for
measures for reduction, etc., and acquires the agreement of the Minister of the Environment

污染源包括小型企业，养殖业，
水产，农业和一般家庭实施建设
和升级污水处理。执行方式包括
建设和改造污水实施和化粪池等

the Pollutant Load by the Standards for the Total Load Reduction

ories and Establishments with 50m³/day or more)
utant load, order to improve measures against the possibility of exceeding the pollutant load

Recommendation for the Reduction of the Pollutant Load

(Small-scale establishments, livestock raising, aqua-farming, agriculture, ordinary households, etc.)

Implementation of Projects such as Construction & Upgrading of Sewerage, Septic Tanks, Etc.

日本重点湖泊环境保护特别措施(法)

内阁决定的湖泊水质保护基本原则



内阁根据各县申报情况确定了10个重点湖泊



10个重点湖泊分别制定湖泊水质保护计划后
通过环境厅提交给环境污染防治会议审核



重点湖泊水污染防治和水质保护计划的核心措施：

- 污染负荷削减：依据水污染控制法要求控制湖泊区域内的小规模畜禽养殖、水产养殖 (指标包括BOD₅、TN和TP)
- 水质控制计划：对影响湖泊水质的生活污水、化粪池、清淤底泥排放实行更严格的控制；实施污染源管制；对非点源排放控制提出改进建议；
- 划定湖周保护区：在湖周保护区内建设水质净化厂；
- (如果有必要)同步实施总量控制策略(COD、TN和TP)。

日本琵琶湖及其生态服务功能(定位=AA类/1级, TN=0.1 mg/L; TP=0.005 mg/L)

可渔



琵琶湖东岸是重要的野生动物栖息地

可喝



琵琶湖引水渠是京都1400万人的水源

可游

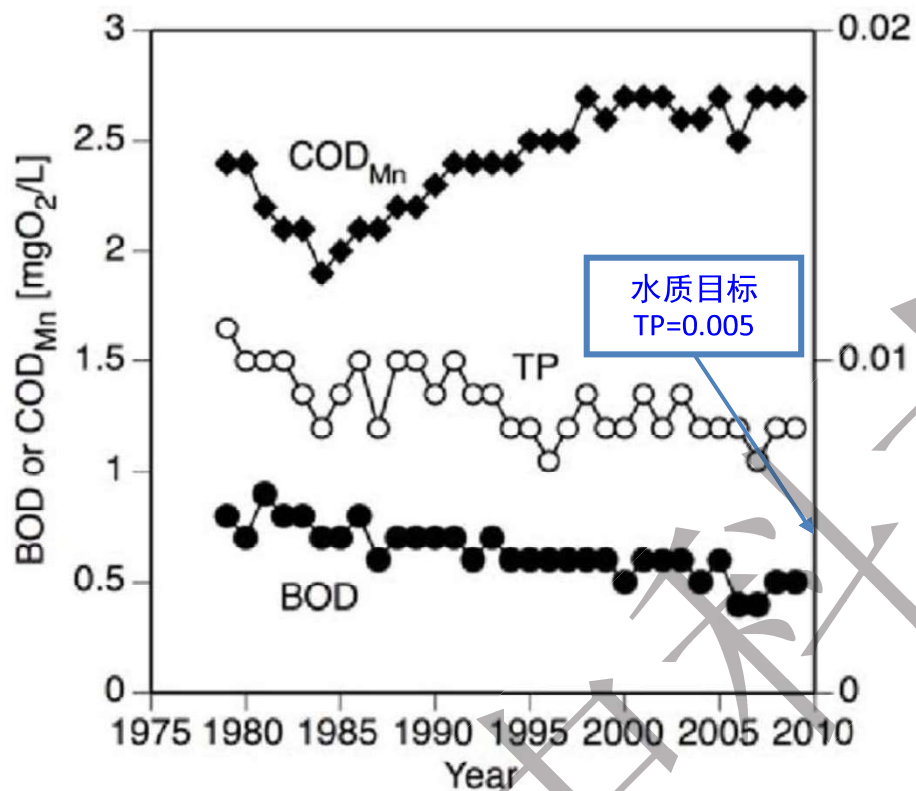


琵琶湖西岸有重要的湖滨沙滩和游泳场

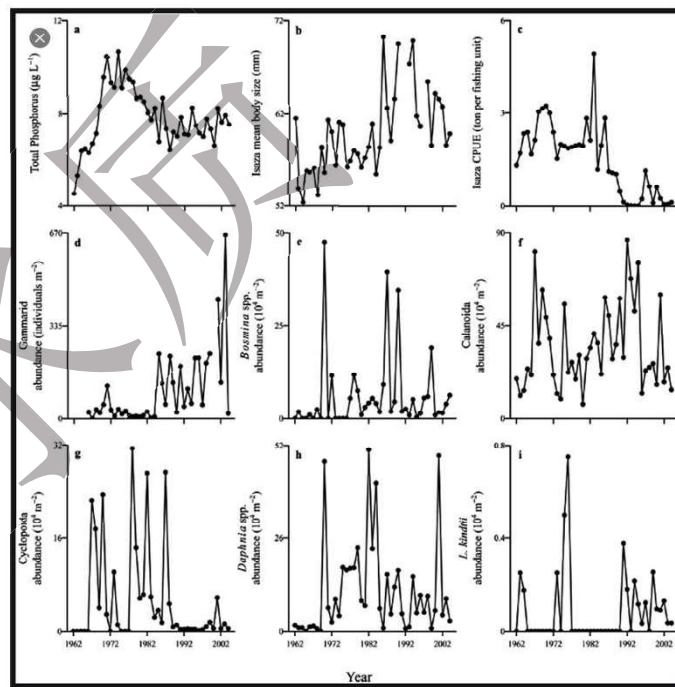


有世界先进水平的湖泊研究所和监测站

日本琵琶湖关键治理期间水质和生物指标的变化



琵琶湖治理关键时期水质指标的变化(共38年)



水生动物的体重指数

琵琶湖治理关键时期生物指标的变化

无论水质能否或是否达到AA类一级的水质标准要求，日本琵琶湖的生态服务功能已经基本恢复

美国的营养盐污染控制策略分析

- 恢复和维持水体的化学、物理和生物完整性、消除污染物排放。阶段性水质保护目标是保护水生生物和景观娱乐(可渔可游)，禁止排放毒性剂量的有毒物质进入水体(101a)

“Biological Assessment—Rather Than Chemistry-- is the Best Way to Assess Aquatic Life Uses”

Also True for Nutrient Pollution Impacts

最好采用生物评价，而不是化学评价方式保护水生生物。对营养盐污染控制亦然。

营养盐能够导致富营养化，后果是导致水体有机质蓄积。如果将重点放在营养盐本身则是误导。生物评价方式可以更好地保护由营养盐污染引起的水体使用功能改变。

- Nutrients can cause eutrophication = excessive accumulation of organic matter
- Focus on alone nutrients can be misleading!
- Biological measures better assessment of beneficial use impacts

从污染物控制到环境质量管理：欧美采用的组合管理方式 A Combination Approach and their Permits

污染源管理

水环境质量管理

排放限制：根据最佳可用技术 (BAT)原则确定的排放污染物
浓度/总量/去除率

水质标准：不会对人类健康和环境产生影响的水、沉积物或生物体中
污染物浓度/含量

许可证制度：同时符合排放标准(技术许可)和水质标准(水质许可)的最大排放浓度/总量

技术许可：点源和部分分散源
管理重点：三类污染物

水质许可：非点源和农业面源
管理重点：特征污染物/有毒物质

美国市政污水排放标准中并没有氮磷营养盐的排放标准或许可



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 14 2012

OFFICE OF WATER

Ms. Ann Alexander, Esq.
Natural Resources Defense Council
2 North Riverside Plaza, Suite 2250
Chicago, Illinois 60606

Dear Ms. Alexander:

Thank you for the November 27, 2007, letter to Administrator Johnson and the accompanying petition on behalf of the Natural Resources Defense Council and ten other organizations requesting that the U.S. Environmental Protection Agency publish updated information about secondary treatment nutrient removal capability and establish new technology-based nutrient limits as part of the secondary treatment standards. The EPA has thoroughly considered the information you provided in the petition. The EPA's decisions concerning your requests are guided by the Agency's commitment to carry out the objective of the Clean Water Act to restore and maintain the nation's waters.

NRDC's first request cites CWA Section 304(d)(1) in asking the EPA to publish updated information on the degree of nutrient reduction attainable through secondary treatment of effluent discharged by municipal wastewater treatment plants, typically known as publically owned treatment works. In response, the EPA is publishing the most current data available on the degree of effluent reduction attainable through the application of secondary treatment. With respect to nutrients in particular, the EPA notes that secondary treatment technology is not designed for nutrient removal. Nevertheless, the EPA sought out information on incidental removals of nutrients by secondary treatment. Not unexpectedly, however, we found that insufficient data exist to draw any general conclusions about the ability of secondary treatment to remove nutrients.

NRDC's second request is for the EPA to establish new generally applicable technology-based nitrogen and phosphorus (nutrients) limitations as part of the secondary treatment regulations for POTWs. After careful consideration, the EPA is denying this request. We find that a uniform set of nationally applicable, technology-based nutrient limits is not warranted at this time. An effort to set such uniform national limits would require POTWs to incur high costs even where such costs are not necessary to protect water quality. In addition, the record indicates that some POTWs face technical constraints to installing more advanced treatment. Instead of pursuing national rulemaking to establish uniform technology-based requirements, the EPA is effectively pursuing the control of nutrient discharges at POTWs by means of site-specific, water-quality-based permitting. The reasons for this decision are discussed more fully below.

.....NRDC要求EPA针对公共污水处理厂(POTWs)在排放标准中增加基于技术的通用氮磷(营养盐)排放标准(TBELs)。经过仔细考虑, EPA拒绝了这一要求。我们发现目前尚不适合建立一套全国适用、以技术为基础的统一营养盐排放标准。如果一定要制定这种统一的国家标准, 则将导致POTWs承担高昂的成本, 而未必是保护水质所必需花费的代价。此外, 有数据表明部分POTWs并不具备升级处理设备的硬件条件。清洁水法并没有要求EPA制定统一营养盐排放标准的国家规则, 而是要求EPA通过个案和基于水质许可的方式有效控制POTWs的营养物质排放。

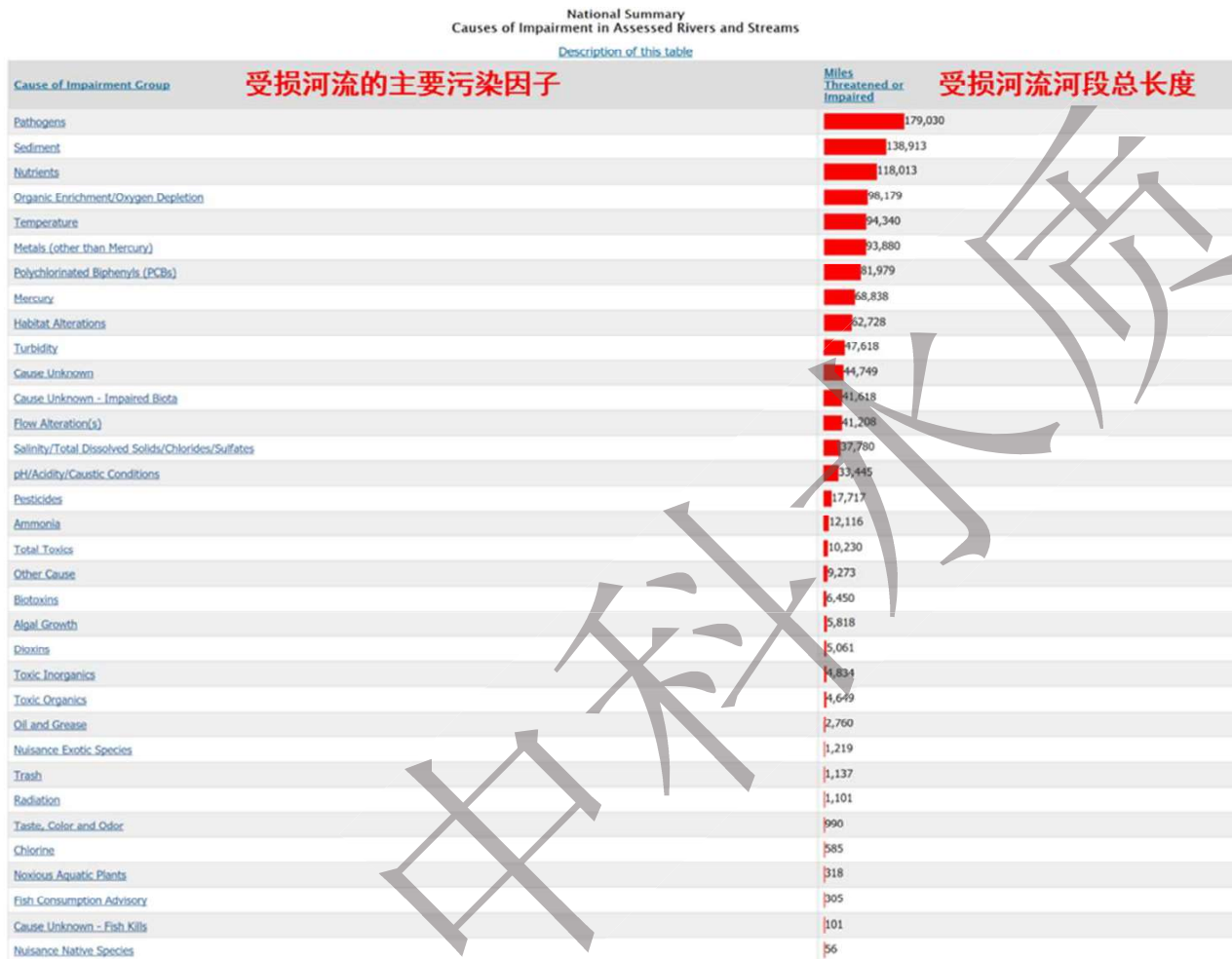
注: NRDC全称是自然资源保护协会, 是一家国际公益环保组织, 成立于1970年。NRDC拥有600多名员工, 以科学、法律、政策方面的专家为主力, 在美国具有很大的社会影响力。

美国加州流域水环境质量的考评指标及其合规性依据的标准(2016年)

评价参数类型	方法及其依据
常规污染物和特征污染物	EPA地面水水质基准中的常规指标(Conventional/None-conventional)
有毒污染物(人体健康/水生生物)	根据美国/加州毒物规则(NTR/CTR)中的指标和EPA地面水基准(PPLs/TSs)
娱乐水体水质目标	根据美国娱乐水体水质标准, 流域规划(BP)和其他政策性文件, 用大肠杆菌和肠球菌2项指标和感官不适指标及其阈值
健康参考(针对摄食野生/养殖鱼类和贝类人群)	根据美国环境健康危害评估办公室(OEHHA)和健康服务部门颁布的法规, 用最大生物组织残留水平(MTRLs)和增量数据水平阈值(EDLs)
水生生物体污染物蓄积(保护野生动物, 如鱼和鸟)	根据水生生物肌肉组织残留量或整体动物残留量数据, 用美国国家科学院(NAS)发表的评估数据
水/沉积物毒性	根据地表水评估监测计划(SWAMP)、南加州海岸水研究计划、ASTM、三藩市河口研究所的河口监测项目和海湾保护与毒物清除项目数据, 采用综合毒性评估(WET)方法确定显著性水平和致毒因子(TIE)
感官不适相关指标	<ol style="list-style-type: none"> 营养盐过高引起的藻类过度生长、非自然形成的泡沫、异味、臭味等 非营养盐引起的异味和臭味、颜色、漂浮油脂、浊度、落叶、垃圾等
有害生物学响应	<ol style="list-style-type: none"> 土著生物生长速率下降、繁殖能力减弱、发育异常、出现显著数量的畸形, 并确认与水质改变有关 肉眼可观察到或半定量估算的死鱼、死鸟现象, 并确认与水质改变有关 由于沉积速率显著改变而引起的生态响应, 如泥沙淤积导致栖息地变化
生物群体/群落退化	生物群体或群落结构发生了显著性改变, 并确认这种改变与水质变化有关, 如化学物质浓度、溶解氧、温度、泥沙淤积等
水质演变趋势分析	水质、沉积物质量、水产品质量、生物群体或群落连续3年持续恶化, 并通过趋势分析证明将来有影响到水质达标

美国联邦EPA并没有统一的营养盐水质基准, 各州根据水体具体使用功能制定营养盐水质标准。

美国国家受损河流的主要污染因子分析(2016年)



- 损伤因子按英里数排序
1. 病原体
 2. 泥沙沉积(水土流失)
 3. 营养盐因子
 4. 有机质和缺氧(BOD物质)
 5. 温度
 6. 重金属(不包括汞)
 7. 多氯联苯
 8. 汞
 9. 浊度
 10. 不明化学因子
 11. 不明生物因子
 12. 水体流速改变
 13. 盐度/TDS/氯离子/硫酸盐
 14. pH/酸度/腐蚀性
 15. 农药
 16. 氨氮
 17. 综合毒性(毒性评价)
 18. 其他原因
 19. 生物毒素
 20. 藻类异常生长
 21. 二噁英
 22. 有毒无机物
 23. 有毒有机物
 24. 油脂类
 25.

依据不同生态分区的营养盐水质标准超标通常指背景值超标(如营养盐因子); 而TMDL中通过因果关系分析(如有机质蓄积和缺氧)确定的营养盐标准并不是一个固定值, 不同区域的差异巨大。

生物评价案例分析：营养盐过量所引起的水污染和水生态系统退化

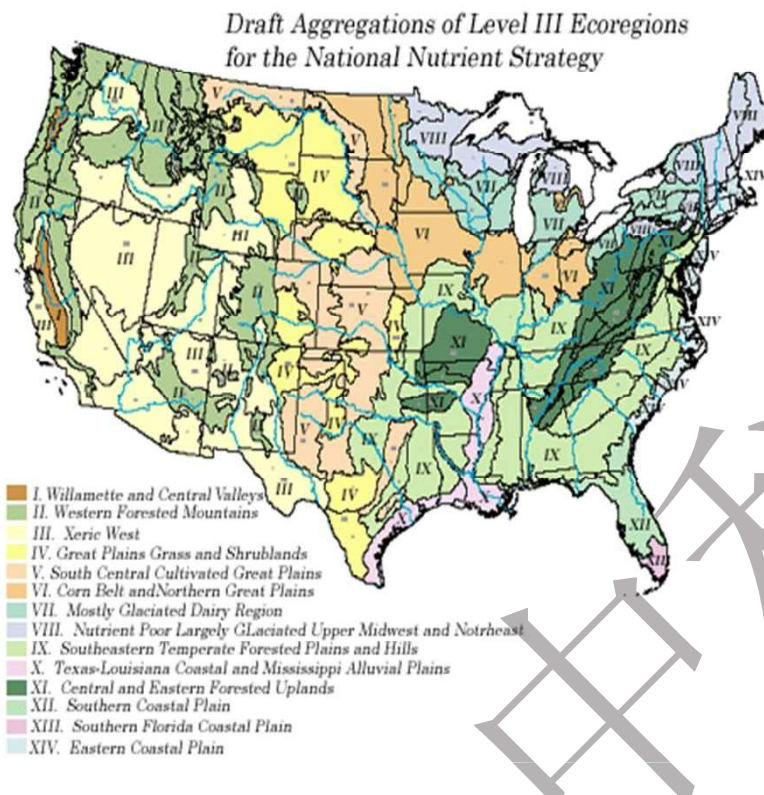
美国广义的营养盐水质标准包括法律和科学两个层面的解释。在法规层面上，营养盐数值标准可支持指定用途的受损水体修复；而在科学层面上，营养盐标准包括富营养化的因变量(压力)和响应变量(如氮或磷浓度)、水生群落响应参数，包括但不限于藻类生物量，叶绿素a和透明度。

(National Strategy for the Development of Regional Nutrient Criteria, EPA, 1998)

营养盐是支持水生态系统健康的核心要素，同时也是导致水生态系统退化的关键污染因子

美国营养盐生态分区标准及推荐的富营养化评价指标

美国地质调查局的营养盐生态分区



湖泊和水库营养盐分区背景值

Parameter	Agg Ecor II	Agg Ecor III	Agg Ecor IV	Agg Ecor V	Agg Ecor VI	Agg Ecor VII	Agg Ecor VIII	Agg Ecor IX	Agg Ecor X	Agg Ecor XI	Agg Ecor XII	Agg Ecor XIII	Agg Ecor XIV
TP µg/L	8.75	17.00	20.00	33.00	37.5	14.75	8.00	20.00	8.00	10.00	17.50	8.00	
TN mg/L	0.10	0.40	0.44	0.56	0.78	0.66	0.24	0.36	0.46	0.52	1.27	0.32	
Chl a µg/L	1.90	3.40	2.00	2.30	8.59	2.63	2.43	4.93	2.79	2.60	12.35	2.90	
Secchi (m)	4.50	2.70	2.00	1.30	1.36	3.33	4.93	1.53	2.86	2.10	0.79	4.50	

河流营养盐分区背景值

Parameter	Agg Ecor I	Agg Ecor II	Agg Ecor III	Agg Ecor IV	Agg Ecor V	Agg Ecor VI	Agg Ecor VII	Agg Ecor VIII	Agg Ecor IX	Agg Ecor X	Agg Ecor XI	Agg Ecor XII	Agg Ecor XIII	Agg Ecor XIV
TP µg/L	47.00	10.00	21.88	23.00	67.00	76.25	33.00	10.00	36.56	128*	10.00	40.00	31.25	
TN mg/L	0.31	0.12	0.38	0.56	0.88	2.18	0.54	0.38	0.69	0.76	0.31	0.90	0.71	
Chl a µg/L	1.80	1.08	1.78	2.40	3.00	2.70	1.50	0.63	0.93	2.10	1.61	0.40	3.75	
Turb FTU/NTU	4.25	1.30	2.34	4.21	7.83	6.36	1.70	1.30	5.70	17.50	2.30	1.90	3.04	

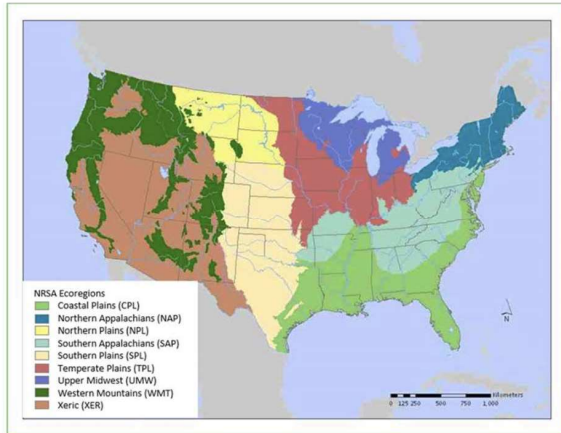
1995年环境保护署关于营养盐基准专家会议上建议避免设定适用于该国所有水体和地区的磷或氮的标准，而建议EPA为全国特定的水体和生态区域制定指导基准(评估工具和控制措施)，并使用反映原始状态或受影响最小的水体的参考条件作为制定当地营养标准的基础。

2012年美国国家湖泊调查(NLA)中采用对应最小干扰状态的参数及其背景值

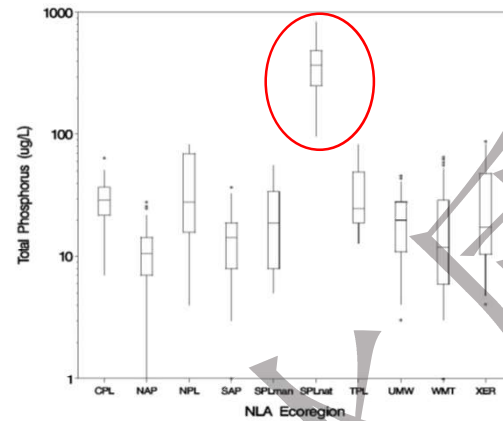
生态分区	TP (µg/L)	TN (µg/L)	Cl (ueq/L)	SO ₄ (ueq/L)	酸度 (ueq/L)	DOC (mg/L)	浊度 (NTU)	HiiNo nAg	Hii- Ag	人类干扰度 (Ag/Res/In d)
WMT	30	400	100	200	25	5	3	0.6	0	5/5/5
XER	100	1000	500	1000	25	5	5	1.5	0.2	5/5/5
NPL	150	2000	1000	---	25	5	5	1.5	0.5	10/6/6
SPL	150	2000	1000	---	25	5	5	1.5	0.5	10/6/6
TPL	120	2000	1000	5000	25	5	5.5	1.7	0.15	9/9/9
UMW	40	1200	200	200	25	5	5	0.6	0	5/5/5
CPL	50	1200	1000	400	25	5	5	1.0	0	6/10/6
SAP	35	800	125	300	25	5	5	0.9	0	6/6/6
NAP	30	600	100	300	25	5	5	0.6	0	6/6/6

相同生态分区的生物类群相关指数具有最大相似性(EPA 采用Omernik四级分区)。因此，将很少受到人类活动干扰样点的生物条件作为参考条件，此时参考点的相关参数就对应了背景值，如总磷和总氮。

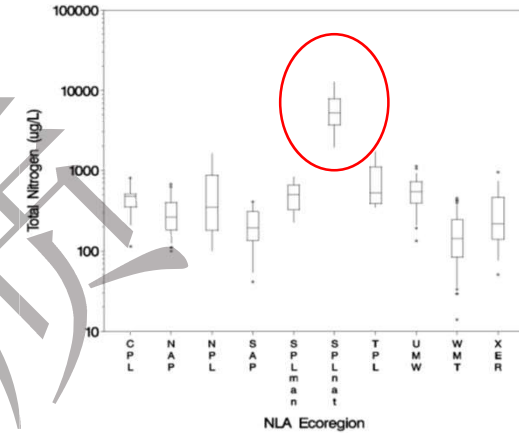
美国湖泊生态状态评价(NLA)中的生态分区参考条件的富营养化参数阈值



富营养化评价参考条件的分区



不同分区总磷浓度和置信度区间



不同分区总氮浓度和置信度区间

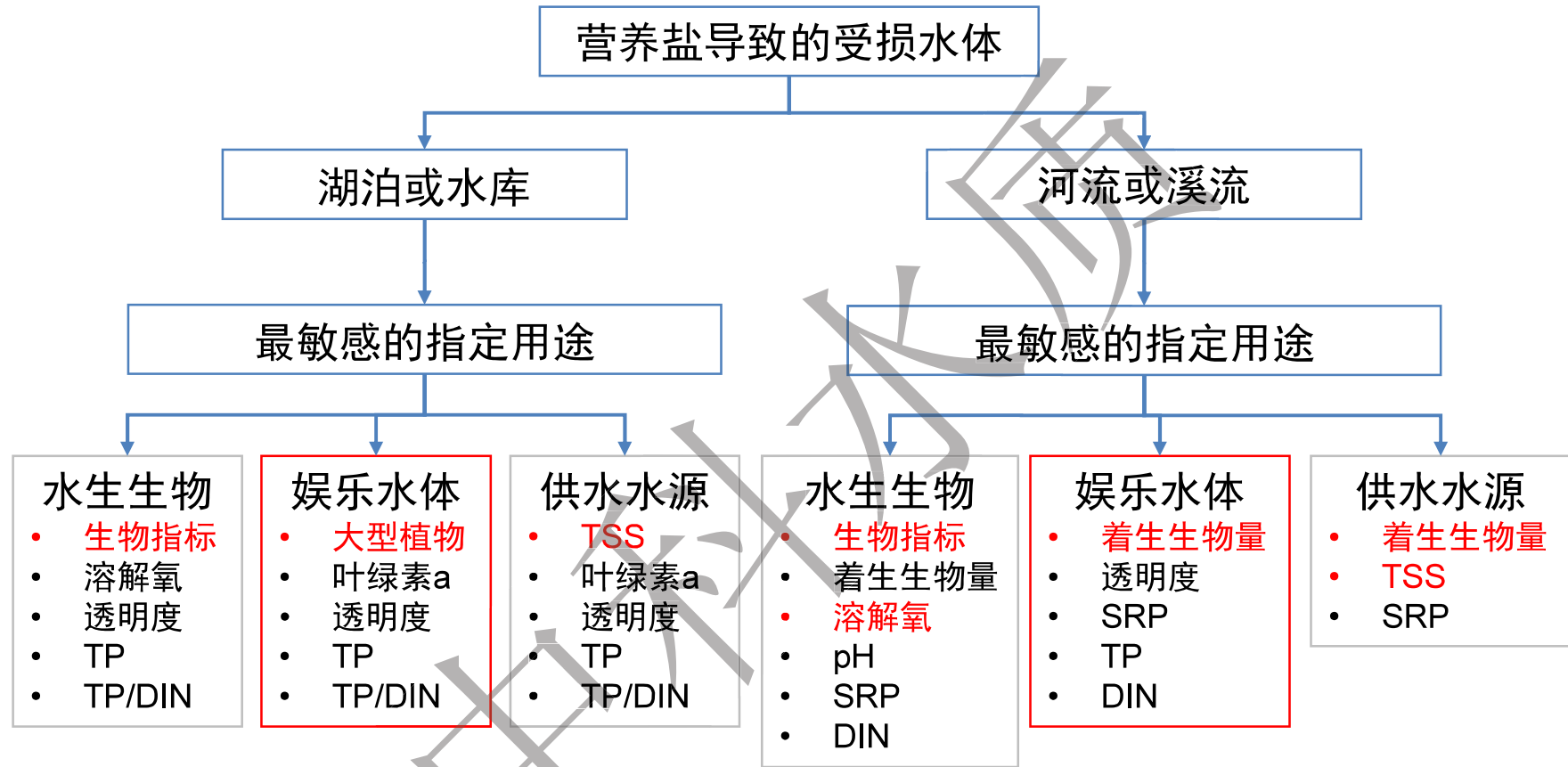
Ecoregion	TP ($\mu\text{g/L}$)		TN ($\mu\text{g/L}$)		Ecoregion	CHLA ($\mu\text{g/L}$)		Turbidity (NTU)	
	75 th Least-moderately	95 th Moderately-Most	75 th Least-moderately	95 th Moderately-Most		75 th Least-moderately	95 th Moderately-Most	75 th Least-moderately	95 th Moderately-Most
CPL	37.0	51.0	510	801	CPL	11.5	28.0	3.38	4.05
NAP	14.5	22.0	400	600	NAP	3.81	7.76	1.10	1.46
NPL	69.5	82.0	866	1,620	NPL	8.53	13.0	3.19	4.46
SAP	19.0	33.0	309	407	SAP	5.23	11.5	2.83	3.94
SPL-manmade	34.0	56.0	657	830	SPL-manmade	6.85	13.8	3.32	4.67
SPL-natural	486	839	7,925	12,875	SPL-natural	118.4	218.7	73.5	172.0
TPL	49.0	82.0	1,105	1,699	TPL	13.9	22.7	3.70	5.38
UMW	28.0	41.0	722	920	UMW	6.70	9.60	2.13	2.89
WMT	29.0	53.0	245	380	WMT	1.83	3.04	0.760	1.43
XER	48.0	84.0	465	746	XER	6.65	12.2	2.97	4.84

数据显示南部平原区的自然湖泊(SPL_{natural})背景值处于超级富营养化状态。资料来源: USEPA NLA报告, 2017

数据显示北部平原区的自然湖泊(NPL_{natural})TP背景值具有最大的变动幅度。资料来源: USEPA NLA报告, 2017

NLA调查数据显示46%河流长度的总磷分级为差, 41%河流长度的总氮分级为差。资料来源: USEPA NRSR报告, 2016

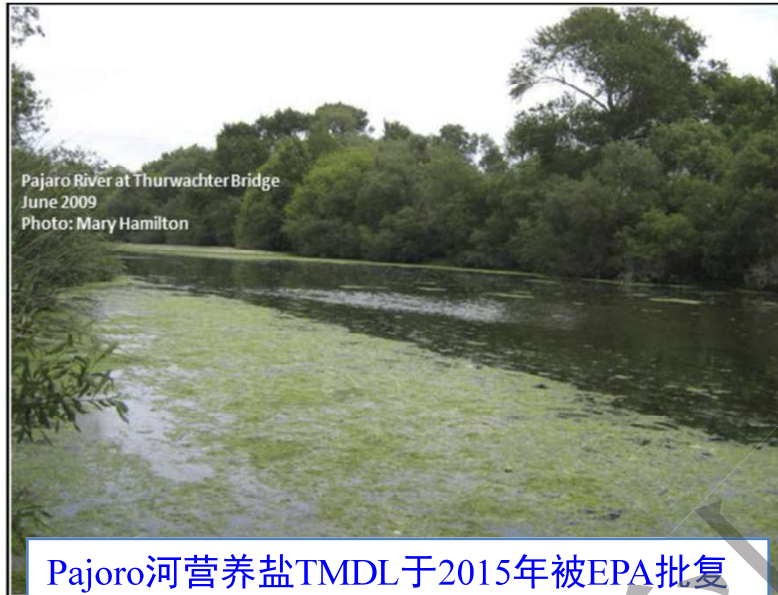
美国水质管理中针对营养盐导致受损水体评价及其参数选择(TMDL路线)



1. 通过营养盐背景值或期望值确定营养盐受损水体，常用TP、SRP或/和DIN；
2. 通过光合植物评价指标推算营养盐受损水体的营养盐控制阈值，常用限制性指标；
3. 通过其他指标如DO/pH/透明度确定营养盐受损水体的营养盐控制方式因地制宜。

资料来源：美国TMDL计划与典型案例实施

美国加州Pajoro生物受损河段(左)和中国承德市区II类河段(右) 状态的比较

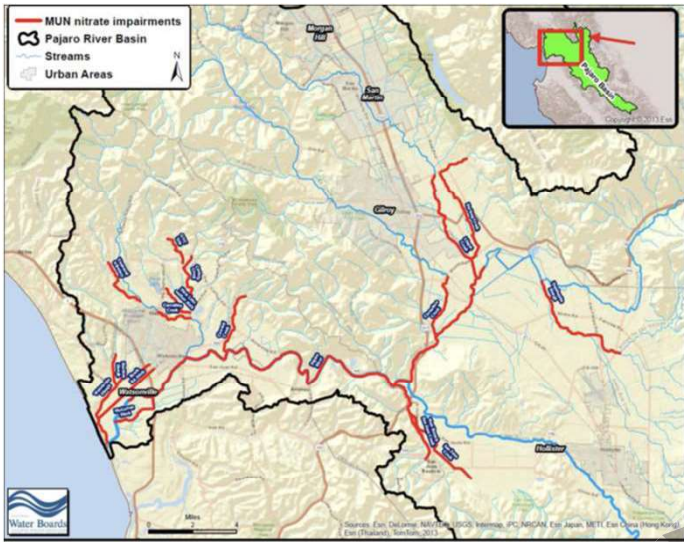


Pajoro河营养盐TMDL于2015年被EPA批复
评价标准选择了DO、叶绿素a和藻毒素

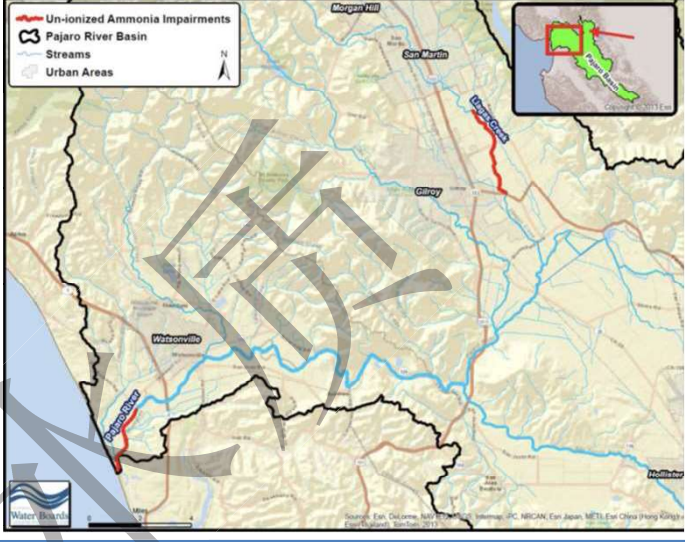


武烈河2020年断面水质达到II类水质标准
评价标准选择了COD、总磷和总氮

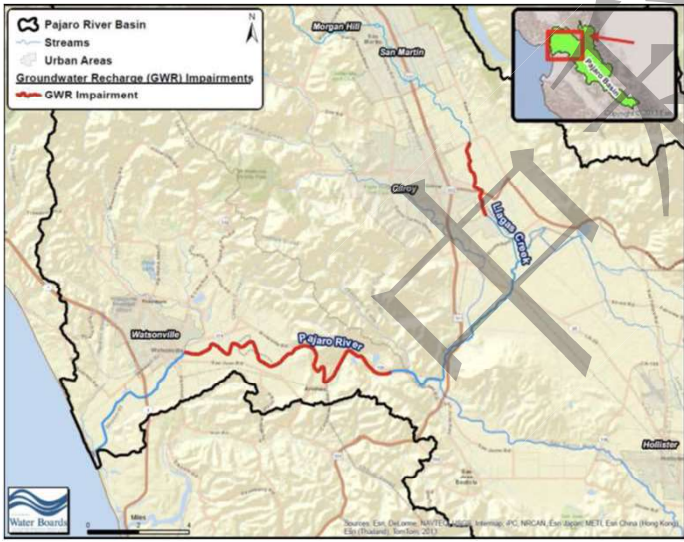
氮超标TMDL水体：美国加州Pajaro河氮污染分功能区的水质标准



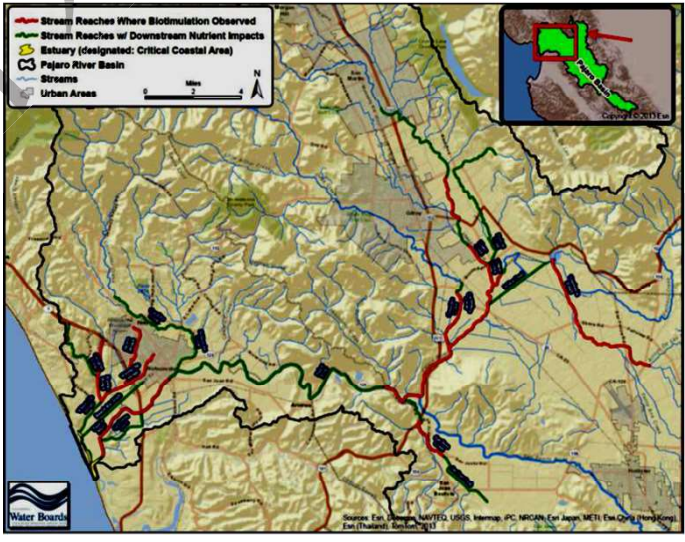
市镇供水水源($\text{NO}_3\text{-N}=10 \text{ mg/L}$)



游离氨生物毒性($\text{NH}_3\text{-N}=0.025 \text{ mg/L}$)

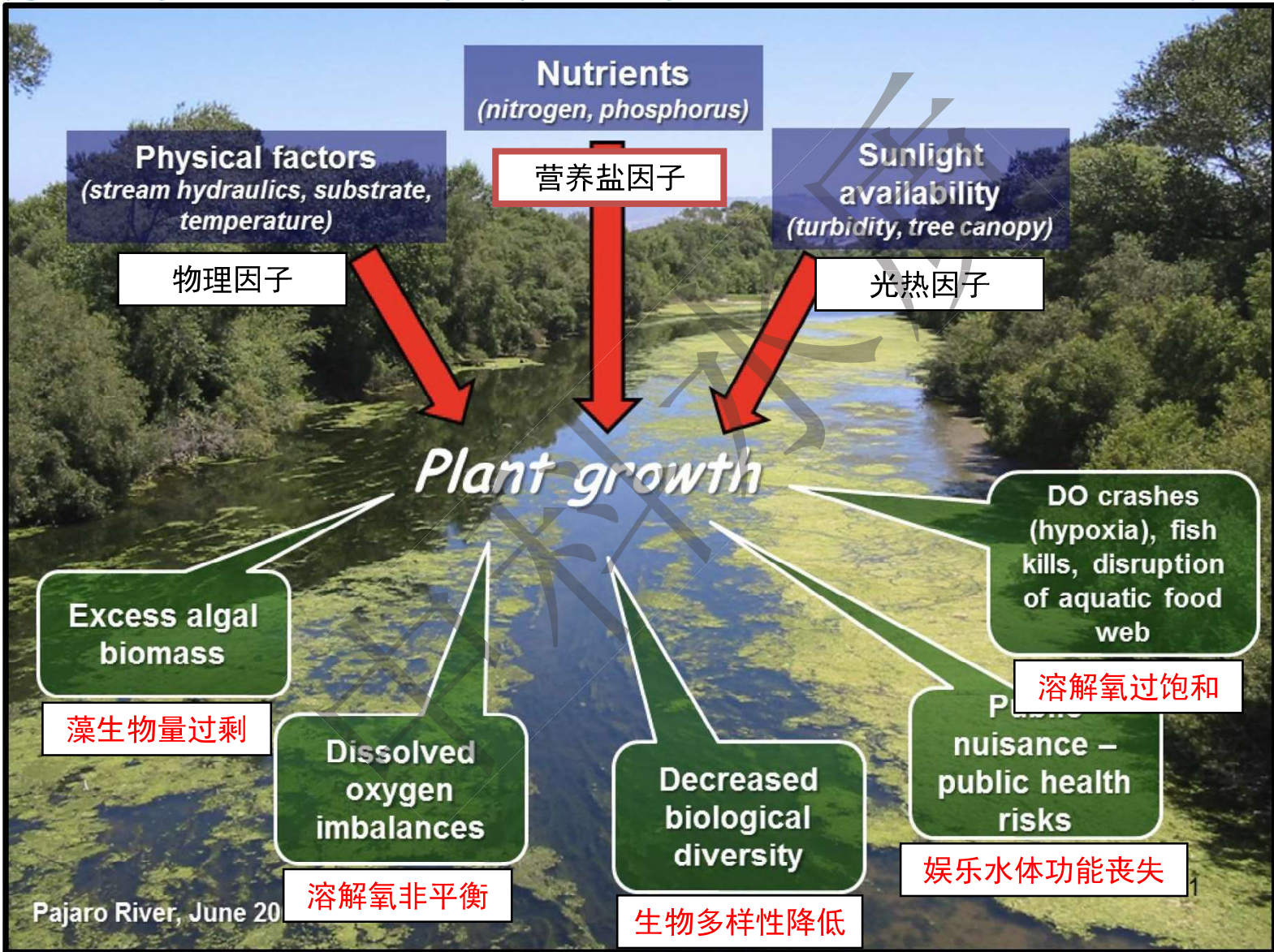


农业用水(硝氮=100 mg/L/亚硝氮=10 mg/L)



溶解氧/pH/生物量/藻毒素 (DO/pH/Chl-a/MC)

Pajoro河的水质指标超标、功能受损及其污染因子相关关系



Pajoro河对应不同四级生态分区的富营养化参数控制标准及其依据(局部)

Stream Reaches Assigned Nitrate (as N) and Orthophosphate Water Quality Targets						
Waterbody Type	Geomorphology & Stream Characteristics	Stream Reaches	Allowable Nitrate as N (mg/L)	Allowable Orthophosphate as P (mg/L)	Methodology for Developing Numeric Target	Notes Pertaining to Development of Targets
Alluvial Floodplain River – Pajaro River	Generally low gradient alluvial basin floor and floodplains. Moderate ambient turbidity (9–21 NTU). Generally moderate canopy cover (20-25%). Substrates variable, but generally characterized by finer-grained material such as loams, clay loams, and fine- sandy loams.	Pajaro River, all reaches including the Pajaro River estuary.	3.9 Dry Season Samples (May 1-Oct. 31)	0.14 Dry Season Samples (May 1-Oct. 31)	Statistical Analysis (USEPA percentile-based approaches) Supplemented by Calif. NNE approach (NNE benthic biomass model tool) Wet-season targets based on Central Coastal Basin Plan nitrate objective and State of Nevada phosphate criteria for streams	Relatively finer-grained substrates and local soil conditions, such as loams, and clay loams likely result in relatively higher ambient turbidity (9–21 NTU) which limits good sunlight penetration of water column; risk of biostimulation thus occurs at relatively higher nutrient concentrations. Orthophosphate water quality targets in the dry season are based on background, reference conditions (USEPA 75 th percentile reference approach) for the Santa Cruz Mountains and Watsonville Plains level IV ecoregions.
			8.0 Wet Season Samples (Nov. 1-Apr. 30)	0.3 Wet Season Samples (Nov. 1-Apr. 30)		
Pajaro Valley –Alluvial Fan & Plains Tributary Creeks	Alluvial fans and alluvial plain tributary reaches. Generally low ambient turbidity (0.1–2 NTU). Generally moderate to higher canopy cover (40-50%). Substrates variable, with finer grained material such as clay loams and sandy loams in lower reaches of these tributaries, and coarser grained material such as gravelly loams and sand in middle reaches of these tributaries.	Corralitos Creek, all reaches	1.8 Dry Season Samples (May 1-Oct. 31)	0.14 Dry Season Samples (May 1-Oct. 31)	Statistical Analysis (USEPA percentile-based approaches) Supplemented by Calif. NNE approach (NNE benthic biomass model tool) Wet-season targets based on Central Coastal Basin Plan nitrate objective and State of Nevada phosphate criteria for streams	丰水期细沙粒引起的浊度高，植物生长受光照限制 Orthophosphate water quality targets in the dry season are based on background, reference conditions (USEPA 75 th percentile reference approach) for the Santa Cruz Mountains and Watsonville Plains level IV ecoregions.
		Salsipuedes Creek, all reaches	8.0 Wet Season Samples (Nov. 1-Apr. 30)	0.3 Wet Season Samples (Nov. 1-Apr. 30)		
Pajaro Valley – Agricultural Ditches	Agricultural ditches located on the basin floor and coastal flood plain of the Pajaro Valley. Low canopy cover (0% to 15%). Substrates expected to be fine-grained mud and clay.	Beach Road Ditch, all reaches	3.3 Dry Season Samples (May 1-Oct. 31)	0.14 Dry Season Samples (May 1-Oct.31)	Statistical Analysis (USEPA percentile-based approaches) Supplemented by Calif. NNE approach (NNE benthic biomass model tool) Wet-season targets based on Central Coastal Basin Plan nitrate objective and State of Nevada phosphate criteria for streams	Substrates expected to be muddy and fine-grained substrates based on local soil conditions which contribute to relatively higher ambient turbidity (up to 19 NTU) which could preclude good sunlight penetration of water column; risk of biostimulation occurs at relatively higher nutrient concentrations.
		McGowan Ditch, all reaches	8.0 Wet Season Samples (Nov. 1-Apr. 30)	0.3 Wet Season Samples (Nov. 1-Apr. 30)		

水体类型

物理生境

河段范围

硝酸盐标准

磷酸盐标准

制定标准依据

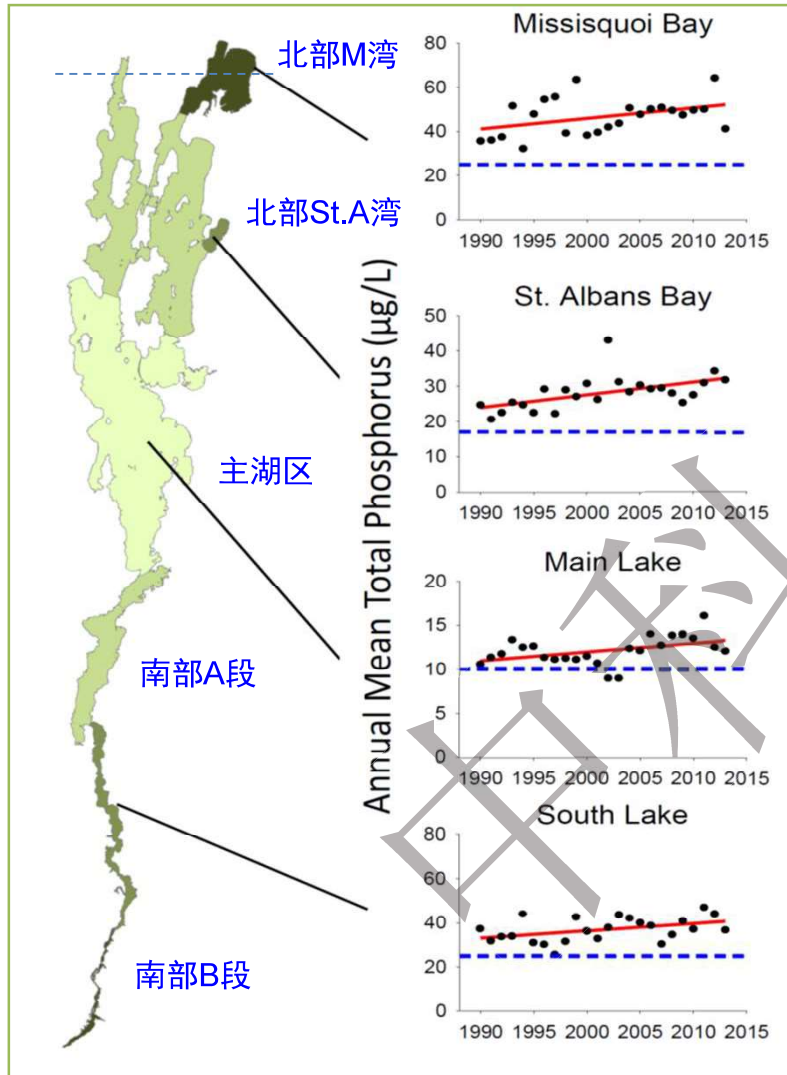
生物超常生长的原因分析



尚普兰湖（Lake Champlain），美国第六大湖，以法国探险家撒母耳·德·尚普兰（Samuel de Champlain）命名，位于纽约州和佛蒙特州交界处，西边是位于纽约州的阿德朗代克山脉，东边则是位于佛蒙特州的绿色山脉。湖水发源于这两山脉，因此它也是世界上最大的高山湖泊。

CHAMPLAIN湖磷TMDL(设定用途包括水生生物保护/景观和娱乐/供水/灌溉)

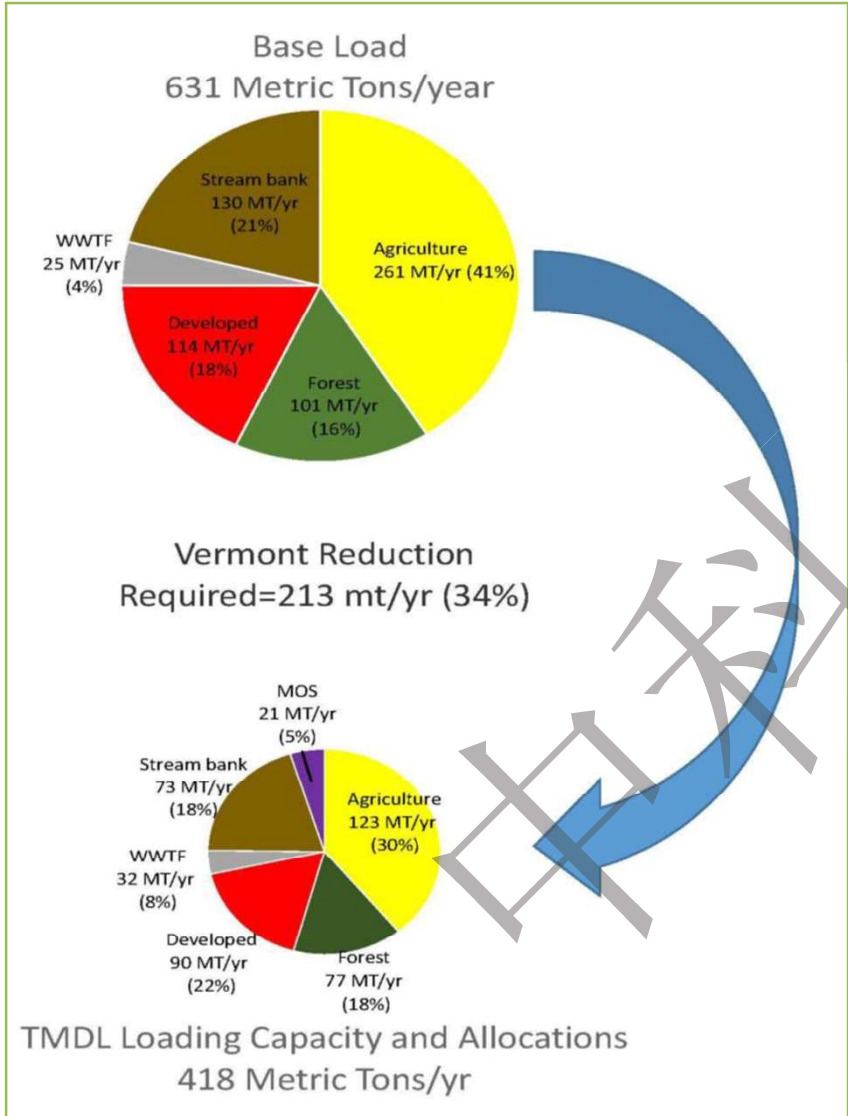
总磷水质标准(全年平均值或中心位置夏季光合层)



Lake Segment	Criterion (mg/l)	Measured Value (mg/l)
South Lake B	0.054 ¹ (0.025 ²)	0.058
South Lake A	0.025	0.034
Port Henry	0.014	0.015
Otter Creek	0.014	0.015
Main Lake	0.010	0.012
Shelburne Bay	0.014	0.015
Burlington Bay	0.014	0.013
Cumberland Bay	0.014	0.014
Malletts Bay	0.010	0.009
Northeast Arm	0.014	0.014
St. Albans Bay	0.017	0.024
Missisquoi Bay	0.025	0.035
Isle LaMotte	0.014	0.012

- 湖泊水质标准(磷限制型湖泊):
- 主湖区: 0.01 mg/L是寡营养大型湖泊的总磷上限
 - St.A湾曾经长期艰苦治理无效, 设定可达性标准
 - 南部A段和北部M湾是浅水草型, 天然富营养化湖湾湾区的鱼类生长需要适当的营养盐条件, 因此水质标准适度放宽到0.025 mg/L
 - 南部B段: 美国和加拿大达成协议的标准是0.025 mg/L, 但是模型表明达标的负荷削减计划不可达。最终采用标准0.045 mg/L
 - 其他湖区: 0.14 mg/L时藻华出现时间占全年1%

美国CHAMPLAIN湖营养盐负荷和削减量分析



1991年分湖区磷负荷分析(总负荷734.3 t/a)

Lake Segment Watershed	1991 Measured Loads ¹			Preliminary Target Allocation ²			TMDL Total Loading Capacity
	Point	Nonpoint	Total	Point	Nonpoint	Total	
Vermont							
South Lake B	3.2	24.8	28.0	1.5	19.3	20.8	20.8
South Lake A	0.1	2.4	2.4	0.1	0.6	0.6	0.6
Port Henry	0.0	0.4	0.4	0.0	0.1	0.1	0.1
Otter Creek	62.8	58.9	121.7	7.1	49.0	56.1	56.1
Main Lake	27.7	60.3	88.0	18.3	58.2	76.6	76.6
Shelburne Bay	5.3	11.1	16.4	0.9	11.0	12.0	12.0
Burlington Bay	11.2	0.3	11.5	2.8	0.3	3.1	5.8
Malletts Bay	3.1	29.8	32.9	2.6	26.1	28.6	28.6
Northeast Arm	0.0	3.2	3.2	0.0	1.2	1.2	1.2
St. Albans Bay	0.8	7.2	8.0	2.4	7.0	9.5	8.0
Missisquoi Bay	6.9 ³	94.2 ³	101.1 ³	5.3	104.4	109.7	58.3 ⁴
Isle LaMotte	0.0	0.6	0.6	0.0	0.3	0.3	0.3
	121.1	293.1	414.2	41.1	277.5	318.6	268.4
Quebec							
Missisquoi Bay	8.5 ³	57.7 ³	66.2 ³	(Included in Vermont Loads)			38.9 ⁵
Vermont/Quebec Total	129.6	350.8	480.4	41.1	277.5	318.6	307.3
New York							
South Lake B	3.9	24.3	28.2	1.9	24.3	26.2	23.9
South Lake A	9.6	3.5	13.1	7.4	2.0	9.4	11.2
Port Henry	1.8	2.6	4.3	0.7	1.8	2.5	3.4
Otter Creek	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Main Lake	7.1	31.8	38.9	4.3	30.8	35.0	33.7
Cumberland Bay	29.2	8.8	38.0	17.2	8.3	25.5	25.2
Isle LaMotte	7.4	20.9	28.3	2.0	19.5	21.5	22.3
	59.0	91.9	150.9	33.5	86.8	120.2	119.8
TOTAL	188.5	442.7	631.3⁶	74.6	364.5	439.1	427.1

美国CHAMPLAIN湖流域营养盐负荷削减中的点源和非点源

- 污水处理厂直接排放(0.2/0.8/5.0 mg/L)
- 工业废水直接排放(0.1/1.0/- mg/L)
- 分流制城市雨污水(MS4)
- 合流制溢流污水(CSO)
- 一些重要场地的雨污水(如工厂)
- 建筑工地雨水
- 集中式畜禽养殖污水(CAFO)
- 通用多部门排污许可(如州级公路和居民区雨水)

Vermont非点源控制污染源(LA)

Vermont Lake Segment Watershed	1991 Total				1991		
	Nonpoint Load (mt/vr) ¹	Forest Load Percent ²	Agric. Load Percent ²	Developed Load Percent ²	Forest Load (mt/vr)	Agric. Load (mt/vr)	Developed Load (mt/vr)
South Lake B	24.8	11.2%	41.4%	47.5%	2.8	10.3	11.8
South Lake A	2.4	2.4%	79.0%	18.6%	0.06	1.9	0.44
Port Henry	0.38	1.2%	75.4%	23.4%	0.00	0.29	0.09
Otter Creek	58.9	6.9%	54.5%	38.6%	4.1	32.1	22.7
Main Lake	60.3	9.6%	17.4%	73.0%	5.8	10.5	44.0
Shelburne Bay	11.1	2.0%	8.7%	89.3%	0.22	1.0	9.9
Burlington Bay	0.27	0.1%	0.3%	99.7%	0.00	0.00	0.27
Malletts Bay	29.8	8.1%	43.7%	48.2%	2.4	13.1	14.4
Northeast Arm	3.2	1.6%	82.0%	16.4%	0.05	2.6	0.52
St. Albans Bay	7.2	0.8%	80.0%	19.3%	0.06	5.8	1.4
Missisquoi Bay	94.2 ²	3.4%	81.1%	15.5%	3.2	76.4	14.6
Isle LaMotte	0.56	2.3%	68.2%	29.6%	0.01	0.38	0.17
TOTAL	293.1				18.7	154.1	120.3

Vermont非点源控制类型(BMPs)

林地：根据卫星影像资料 and 不同景观单元对应的排放因子计算，包括植被类型，土壤地质和水文条件
 农用地：根据卫星影像资料 and 植被类型对应的排放因子计算，包括种植属性，肥料施用和灌溉模式
 建成区域：主要指不在NPDES许可范围的污染源，包括居民点，乡村道路，堤岸侵蚀，河道侵蚀等

Vermont的NPDES控制污染源(WLA)

Vermont Facility	Lake Segment	Current Permit Flow Limit (mgd)	Current Permit Conc. Limit (mg/l)	Current Permit Load Limit (lbs/day)	Default Conc. Limit (mg/l)	Currently Permitted Annual Load (mt/vr)	TMDL Wasteload Allocation (mt/vr)	Reduction in Permitted Load (mt/vr)
Alburg	Isle LaMotte	0.130	1.0			0.180	0.108	0.072
Barre City	Main Lake	4.000	0.8	22.7		3.759	3.314	0.445
Benson	South Lake B	0.018			5.0	0.122	0.122	
Brandon	Otter Creek	0.700	0.8	4.7		0.778	0.580	0.198
Brown Ledge Camp	Malletts Bay	0.004	1.0			0.005	0.005	
Burlington East	Main Lake	1.200	0.8	8.0		1.325	0.994	0.330
Burlington Electric	Main Lake	0.125	0.1	0.1		0.017	0.017	
Burlington Main	Burlington Bay	5.300	0.8	33.4		5.531	4.392	1.139
Burlington North	Main Lake	2.000	0.8	13.3		2.202	1.657	0.545
Cabot	Main Lake	0.050	0.8	0.3		0.055	0.041	0.013
Castleton	South Lake B	0.480	0.8	2.4		0.397	0.397	
Enosburg Falls	Missisquoi Bay	0.450	0.8	3.0		0.497	0.373	0.124
Essex Junction	Main Lake	3.100	0.8	18.4		3.047	2.569	0.478
Fair Haven	South Lake B	0.500				0.546	0.414	0.132
Fairfax	Malletts Bay	0.078	0.8	3.3		0.539	0.539	
Hardwick	Malletts Bay	0.371			5.0	2.562	0.410	2.152
Hinesburg	Shelburne Bay	0.250	1.0	2.1		0.348	0.276	0.072
IBM	Main Lake	8.000	0.8	33.4		5.531	5.531	
Jeffersonville	Malletts Bay	0.077			5.0	0.532	0.532	
Johnson	Malletts Bay	0.270	0.8	1.8		0.298	0.224	0.074
Marshfield	Main Lake	0.045			5.0	0.311	0.311	
Middlebury	Otter Creek	2.200	0.8	14.7		2.434	1.823	0.611
Milton	Malletts Bay	1.000	0.8	6.7		1.110	0.829	0.281
Montpelier	Main Lake	3.970	0.8	26.5		4.388	3.290	1.099
Morrisville	Malletts Bay	0.425	0.8	2.8		0.464	0.352	0.112
Newport Center	Missisquoi Bay	0.042			0.1	0.006	0.006	
North Troy	Missisquoi Bay	0.110			5.0	0.760	0.760	
Northfield	Main Lake	1.000	0.8	6.78		1.123	0.829	0.294
Northwest State Correctional	St. Albans Bay	0.040	0.5			0.028	0.028	
Oryell	South Lake A	0.033			5.0	0.228	0.228	
Otter Valley Union High School	Otter Creek	0.025			5.0	0.173	0.173	
Pittsford	Otter Creek	0.070			5.0	0.483	0.483	
Pittsford Fish Culture Station	Otter Creek	5.000			0.1	0.691	0.691	
Plainfield	Main Lake	0.100			5.0	0.691	0.691	
Poultney	South Lake B	0.500	0.8	2.64		0.437	0.414	0.023
Proctor	Otter Creek	0.325			5.0	2.244	0.359	1.885
Richford	Missisquoi Bay	0.380			5.0	2.624	0.420	2.204
Richmond	Main Lake	0.222	0.8	1.48		0.245	0.184	0.061
Rock Tenn	Missisquoi Bay	3.500	0.8	21.0		3.478	1.260	2.218
Rutland City	Otter Creek	6.800	0.8	45.4		7.518	5.634	1.884
Salisbury Fish Culture Station	Otter Creek	1.310			0.1	0.181	0.181	
Shelburne #1	Shelburne Bay	0.440	0.8	2.1		0.348	0.348	
Shelburne #2	Shelburne Bay	0.660	0.8	3.0		0.497	0.497	
Sheldon Springs	Missisquoi Bay	0.054			5.0	0.373	0.373	
Shoreham	Otter Creek	0.035			5.0	0.242	0.242	
South Burlington Airport Park.	Main Lake	2.300	0.8	15.3		2.534	1.906	0.628
South Burlington Bart. Bay	Shelburne Bay	1.250	0.8	5.3		0.878	0.878	
St. Albans City	St. Albans Bay	4.000	0.5			2.762	2.762	
Stowe	Main Lake	1.000	0.8	1.7		0.282	0.282	
Swanton	Missisquoi Bay	0.900	1.0	7.5		1.242	0.746	0.496
Troy/Jay	Missisquoi Bay	0.200			5.0	1.381	0.221	1.160
Vergennes	Otter Creek	0.750	1.0	5.5		0.911	0.621	0.289
Wallingford	Otter Creek	0.120			5.0	0.829	0.829	
Waterbury	Main Lake	0.510			5.0	3.522	0.563	2.958
Weed Fish Culture Station	Main Lake	11.500		5.52		0.914	0.914	
West Pawlet	South Lake B	0.040			5.0	0.276	0.276	
West Rutland	Otter Creek	0.450	0.8	2.2		0.364	0.364	
Williamstown	Main Lake	0.150			5.0	1.036	1.036	
Winooski	Main Lake	1.400	0.8	8.0		1.325	1.160	0.165
Wyeth	Malletts Bay	0.425	0.78	3.0		0.497	0.352	0.145
TOTAL						78.1	55.8	22.3

美国清洁水法中各州的水体营养盐标准完成情况统计(2016)

State	N/P - 1998	N/P - 2008	N/P - Current	Chlorophyll
Alabama	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 2 ○○○○
Alaska	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
American Samoa	Level 5 ●●●●	Level 5 ●●●●	Level 5 ●●●●	Level 3 ○○○○
Arizona	Level 2 ⊕⊕⊗	Level 2 ⊕⊕⊗	Level 2 ⊕⊕⊗	Level 1 ○○○○
Arkansas	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
California	Level 2 ⊕⊕⊕	Level 2 ⊕⊕⊕	Level 2 ⊕⊕⊕	Level 2 ○○○○
Colorado	Level 1 ○○○○	Level 2 ⊕○○	Level 2 ⊕○○	Level 2 ○○○○
Connecticut	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Delaware	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
District of Columbia	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 3 ○○○○
Florida	Level 1 ○○○○	Level 1 ○○○○	Level 4 ●●●●	Level 4 ●●●●
Georgia	Level 2 ⊕○○	Level 2 ⊕○○	Level 2 ⊕○○	Level 2 ○○○○
Guam	Level 5 ●●●●	Level 5 ●●●●	Level 5 ●●●●	Level 1 ○○○○
Hawaii	Level 5 ⊗●●●	Level 5 ⊗●●●	Level 5 ⊗●●●	Level 3 ⊗○○○
Idaho	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Illinois	Level 2 ⊕○○	Level 2 ⊕○○	Level 2 ⊕○○	Level 1 ○○○○
Indiana	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Iowa	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Kansas	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Kentucky	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Louisiana	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Maine	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Marshall Islands	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Massachusetts	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Michigan	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Minnesota	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Mississippi	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Missouri	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Montana	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Nebraska	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Nevada	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
New Hampshire	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
New Jersey	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
New Mexico	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
New York	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
North Carolina	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
North Dakota	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Ohio	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Oklahoma	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Oregon	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Pennsylvania	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Rhode Island	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
South Carolina	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
South Dakota	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Tennessee	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Texas	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Utah	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Vermont	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Virginia	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Washington	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
West Virginia	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Wisconsin	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○
Wyoming	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○	Level 1 ○○○○

United States Environmental Protection Agency
Office of Water 4304
EPA 822-R-98-002 June 1998

EPA National Strategy for the Development of Regional Nutrient Criteria

June 1998

明尼苏达州水质标准中的营养盐标准 (部分)

Lake Zumbro, Segment 2	Eutrophication: Total phosphorus Chl-a Secchi depth	7050.0220 subp. 7 Site-specific modifications of standards	TP: < 105 µg/L Chl-a: < 48 µg/L Secchi depth: ≥ 1.1 m	8/28/2018
Lake Zumbro, Segment 3	Eutrophication: Total phosphorus Chl-a Secchi depth	7050.0220 subp. 7 Site-specific modifications of standards	TP: < 75 µg/L Chl-a: < 40 µg/L Secchi depth: ≥ 1.4 m	8/28/2018
Spring Lake (70-0054-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: 60 µg/L Chl-a: 20 µg/L Secchi disk transparency: 1.4 m	7/19/2016
Lake Winona (21-0081-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: 75 µg/L Chl-a: 20 µg/L Secchi disk transparency: 1.0 m	6/12/2014
Lake Nokomis (27-0019-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: < 50 µg/L Chl-a: < 20 µg/L Secchi disk transparency: 1.4 m	9/9/2013
Lake Hiawatha (27-0018-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: < 50 µg/L Chl-a: 14 µg/L Secchi disk transparency: 1.4 m	7/24/2013

Minnesota

2 or more watertypes with N and/or P criteria (Level 4)

- Lakes/Reservoirs
 - Statewide P Criteria
- Rivers/Streams
 - Statewide P Criteria
- Estuaries
 - Watype Not Applicable

明尼苏达州部分湖泊水质标准中的富营养化参数阈值

Lake Zumbro, Segment 2	Eutrophication: Total phosphorus Chl-a Secchi depth	7050.0220 subp. 7 Site-specific modifications of standards	TP: < 105 µg/L Chl-a: < 48 µg/L Secchi depth: ≥ 1.1 m	8/28/2018
Lake Zumbro, Segment 3	Eutrophication: Total phosphorus Chl-a Secchi depth	7050.0220 subp. 7 Site-specific modifications of standards	TP: < 75 µg/L Chl-a: < 40 µg/L Secchi depth: ≥ 1.4 m	8/28/2018
Spring Lake (70-0054-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: 60 µg/L Chl-a: 20 µg/L Secchi disk transparency: 1.4 m	7/19/2016
Lake Winona (21-0081-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: 75 µg/L Chl-a: 20 µg/L Secchi disk transparency: 1.0 m	6/12/2014
Lake Nokomis (27-0019-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: < 50 µg/L Chl-a: < 20 µg/L Secchi disk transparency: 1.4 m	9/9/2013
Lake Hiawatha (27-0018-00)	Eutrophication: Total phosphorus Chl-a Secchi disk transparency	7050.0222 subp.4 Eutrophication standards	TP: < 50 µg/L Chl-a: 14 µg/L Secchi disk transparency: 1.4 m	7/24/2013

欧盟的排放标准与营养盐污染控制策略分析

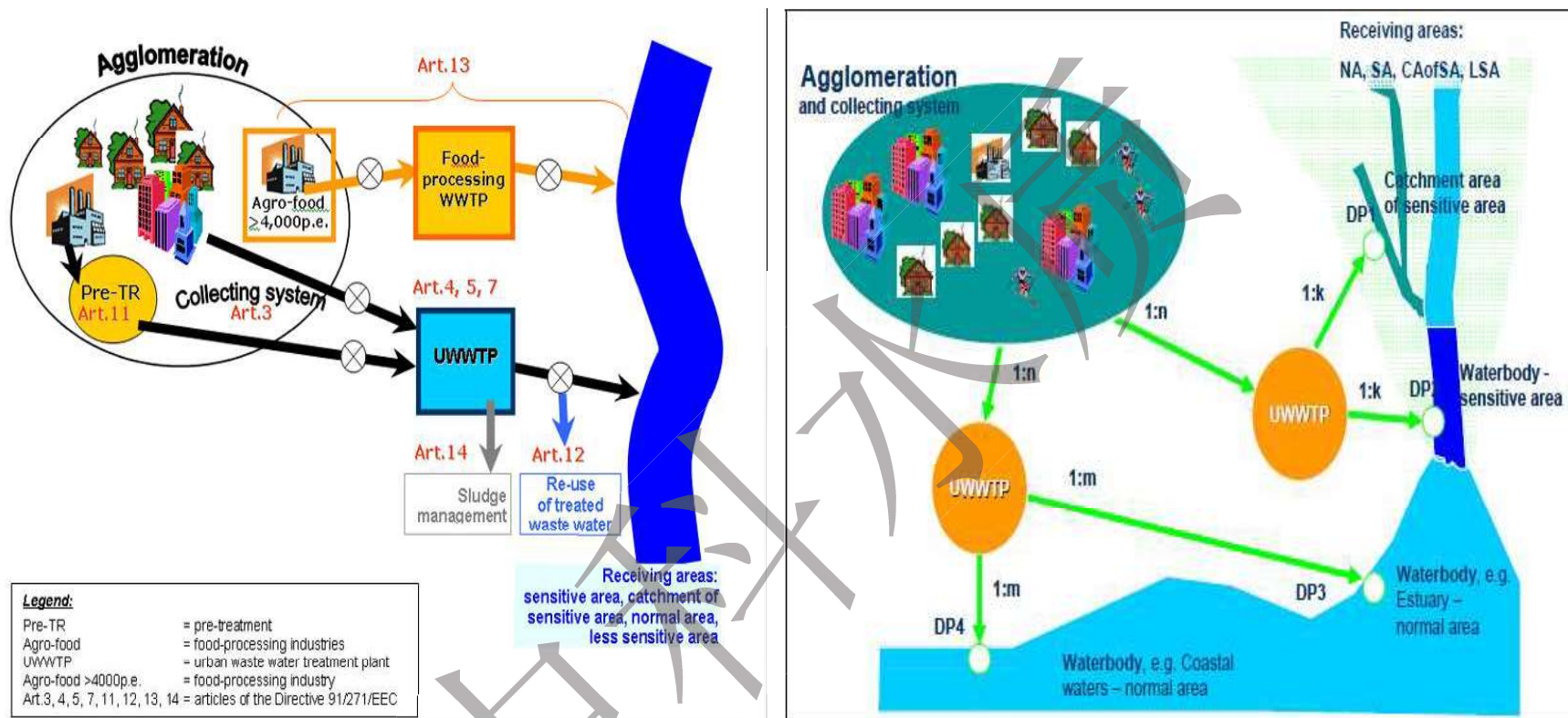
- 为保护水生态系统直接相关的各种水资源利用、防止陆地生态系统和湿地进一步退化、提高水生态系统优良等级(article 1a)

欧盟市政污水处理指令(91/271/EEC)中的排放限制¹

参数	浓度限制(mg/L)	去除率限制(%)	测试方法
BOD ₅ ²	25	70~90	加入硝化抑制剂测定c-BOD
COD/TOC	125	75	重铬酸钾氧化/TOC仪法
TSS	35 (>10 000 p.e.) 60 (2000~10 000 p.e.)	90 70	1. 0.45μm膜滤-烘干-称重 2. 2800~3200g离心-烘干-称重
TP ³	2 (10 000~100 000 p.e.) 1 (> 100 000 p.e.)	80	分子吸收光谱
TN ³	15 (10 000~100 000 p.e.) 10 (> 100 000 p.e.)	70~80	分子吸收光谱

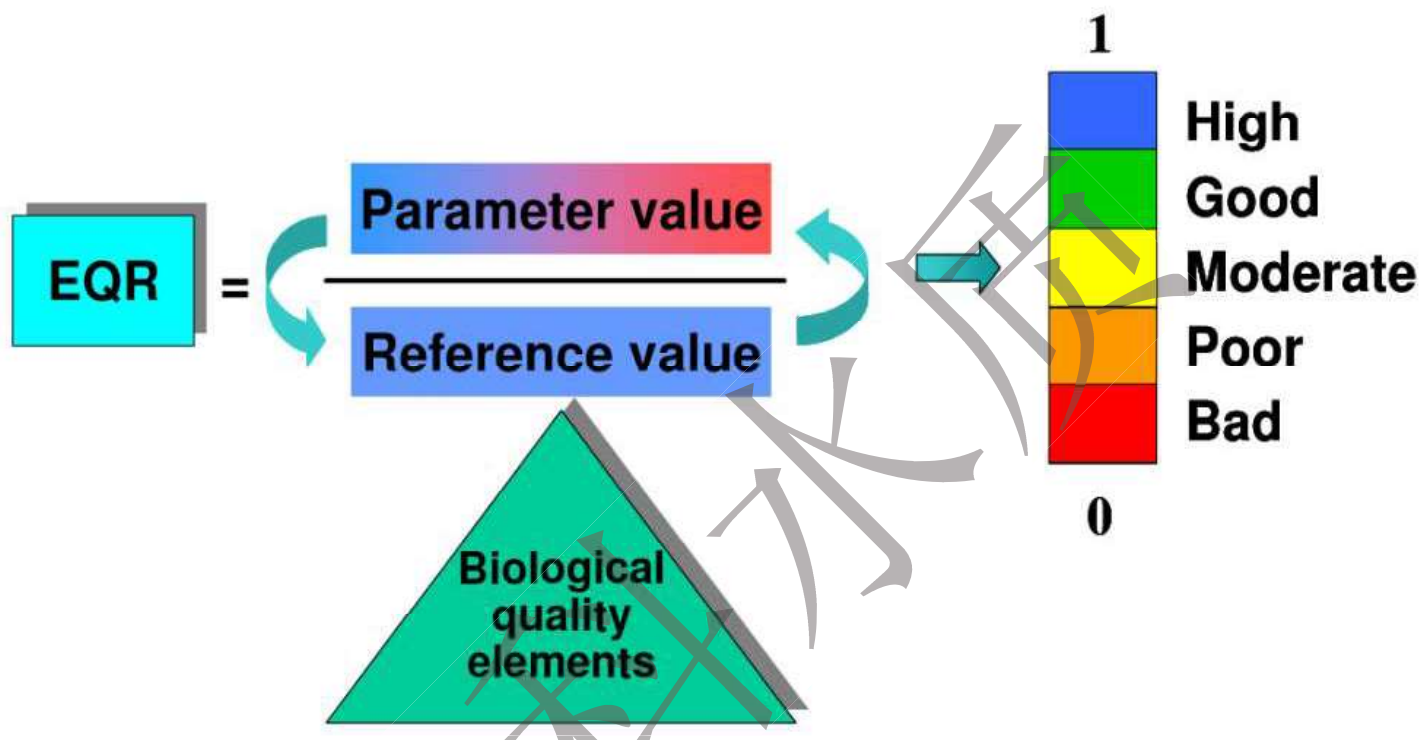
1. 排放限值按照人口当量(p.e.)分级计算, 单位p.e.相当于60g BOD₅/d排放量
2. BOD₅指标可以用TOC或COD指标代替, BOD:COD=1:5换算, 或TOC:COD=1:3换算
3. 氮磷指标仅适用于富营养化敏感区域, 可根据具体情况选择TP或TP+TN
4. 如果存在欧盟其他指令性要求的限制, 应该服从这些指令的相关规定, 如氮控制指令

欧盟市政污水处理指令(91/271/EEC)



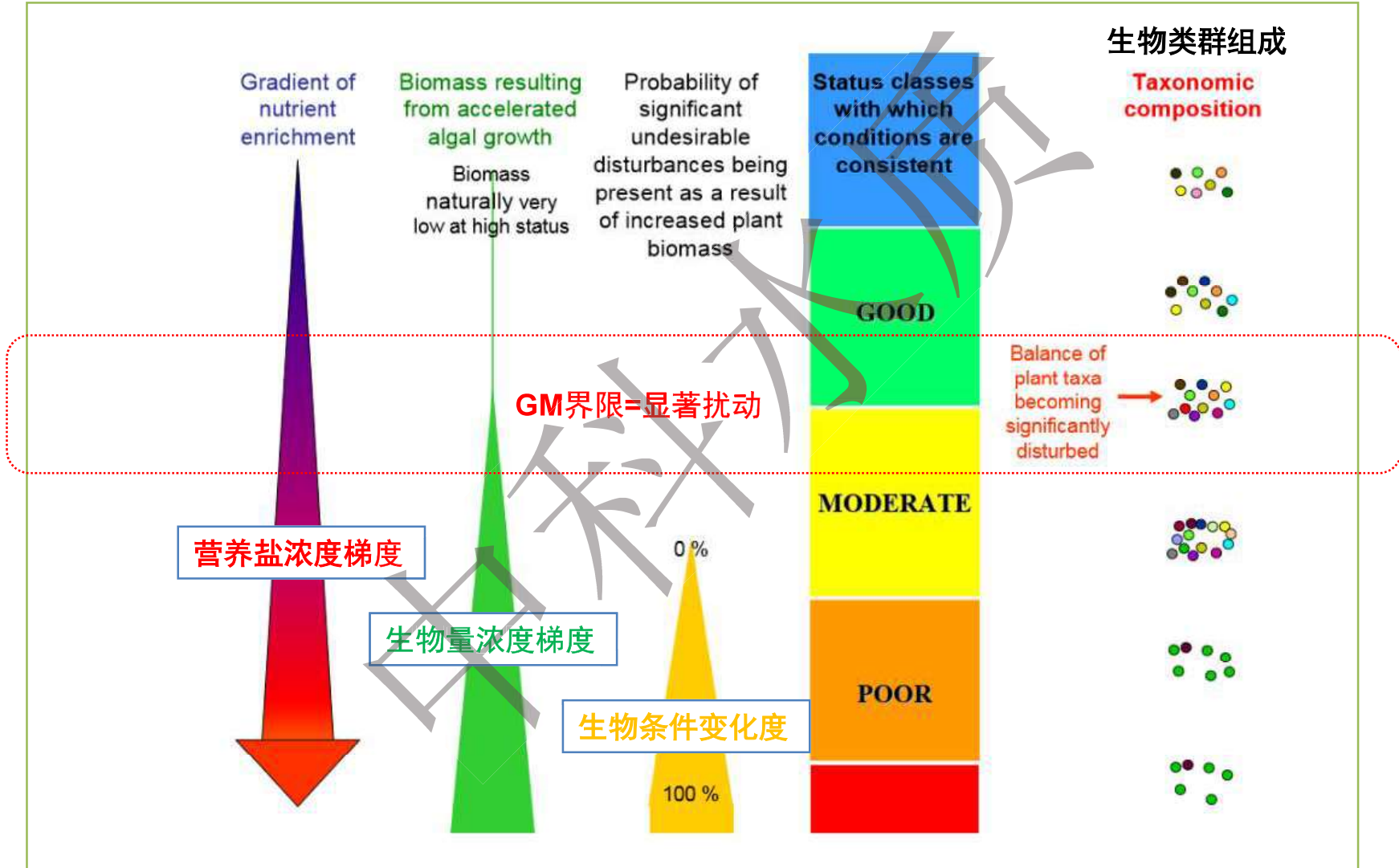
- 食品加工废水单独处理后按照市政污水排放标准执行
- 对生活污水排入(营养盐)非敏感水体(DP3&DP4)可以不执行氮、磷排放限制，BOD和TSS按照1：m稀释倍数计算；
- 对生活污水排入敏感水体(DP1&DP2)执行磷排放标准为1 mg/L (10000~100000 p.e.)或2 mg/L(>100000 p.e.)，全部4项指标按照1：k稀释倍数计算；
- DP1包括湖泊和/封闭海湾/，DP2包括流入湖泊/封闭海湾/河口的河流。

水框架指令中采用的归一化记分方式：生态质量比(Ecological Quality Ratio)

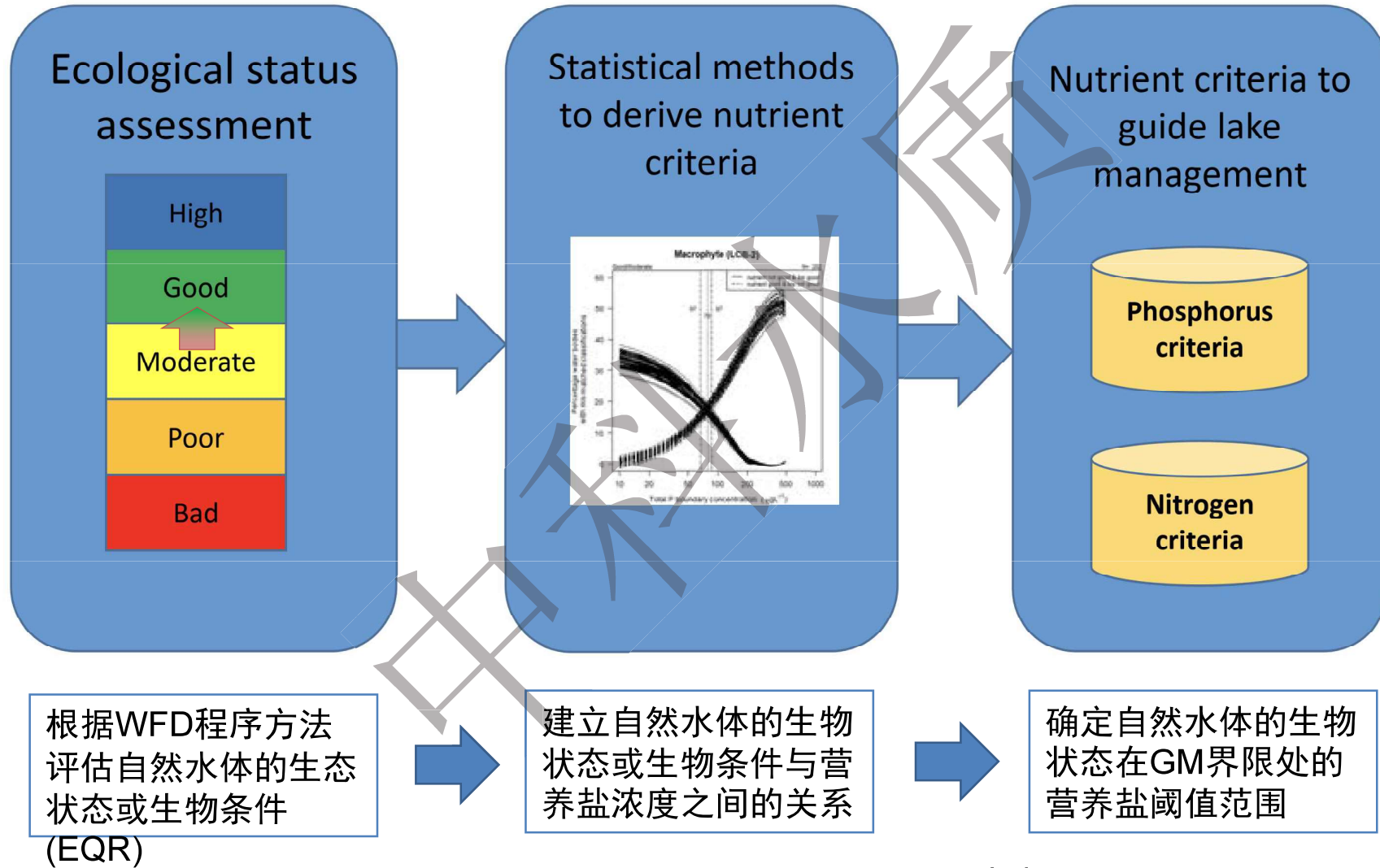


- 生态质量比(EQR)是给定地表水水体的观测生物参数值与参考条件下的期望值之比。比例应表示为0 ~ 1之间的数值，生态状态为“High”时EQR接近1，生态状态“Bad”时以接近0的数值表示。参考条件下的评价指数大于观察值时用负数转化。
- 采用归一化的EQR量度可以协调不同评价指标和方法所得到的结果，降低不同国家EQR取值不确定性和提高可比性，因此EQR采用类别水体作为参照来“铆钉”评估结论。
- 为了将不同国家和不同水体类型EQRs统一到相同尺度，欧盟采用了交叉参照(IC)路线。
- 进一步将WFD的评价结果与其他如生境保护法规统一，欧盟再次建立新的交叉参照(BT)。

水框架指令中的GM界限：由于营养盐蓄积引起的水生态系统退化存在“突变点”



欧盟水框架指令根据水体自然生态状态确定营养盐标准的技术路线

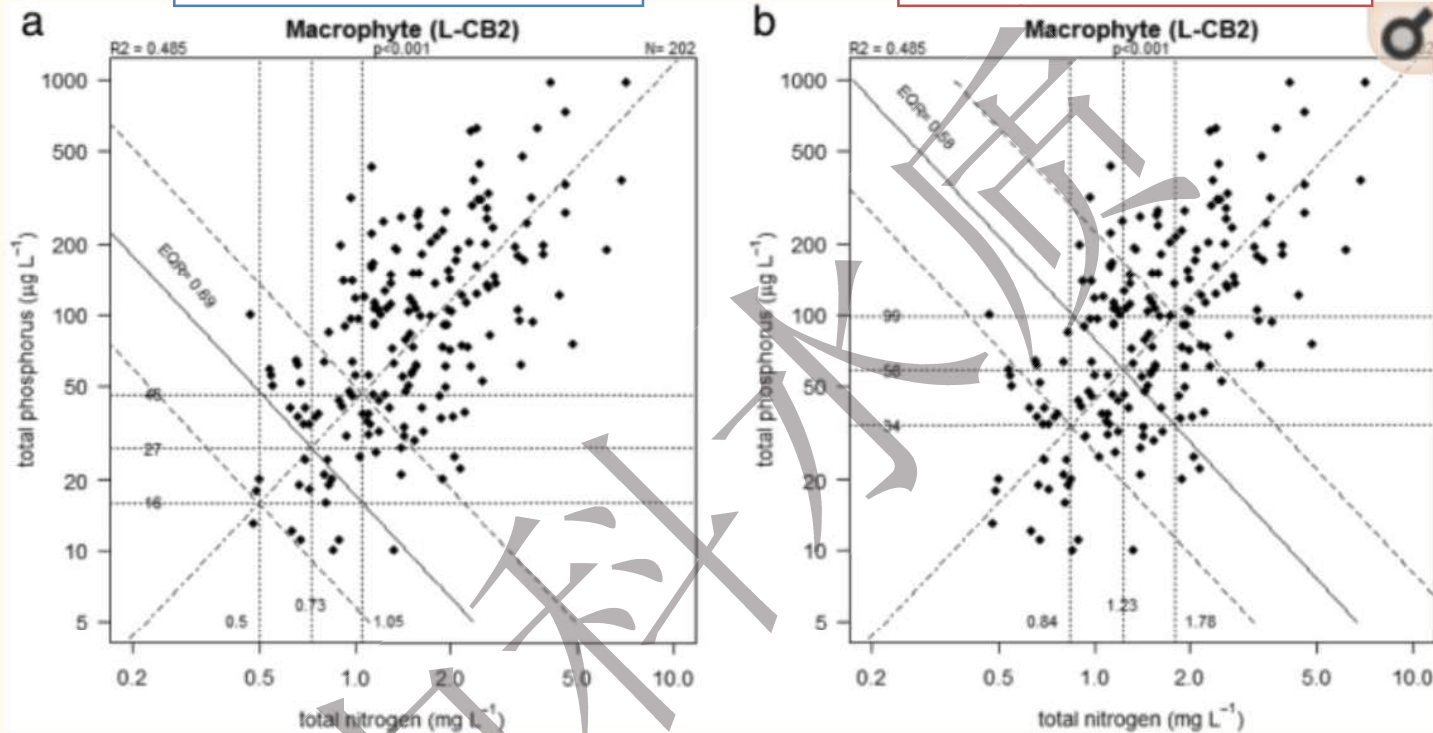


(根据Sandra Poikane, 2019)

根据水体生物条件确定HG和GM界限的营养盐阈值范围

HG界限(EQR=0.89)

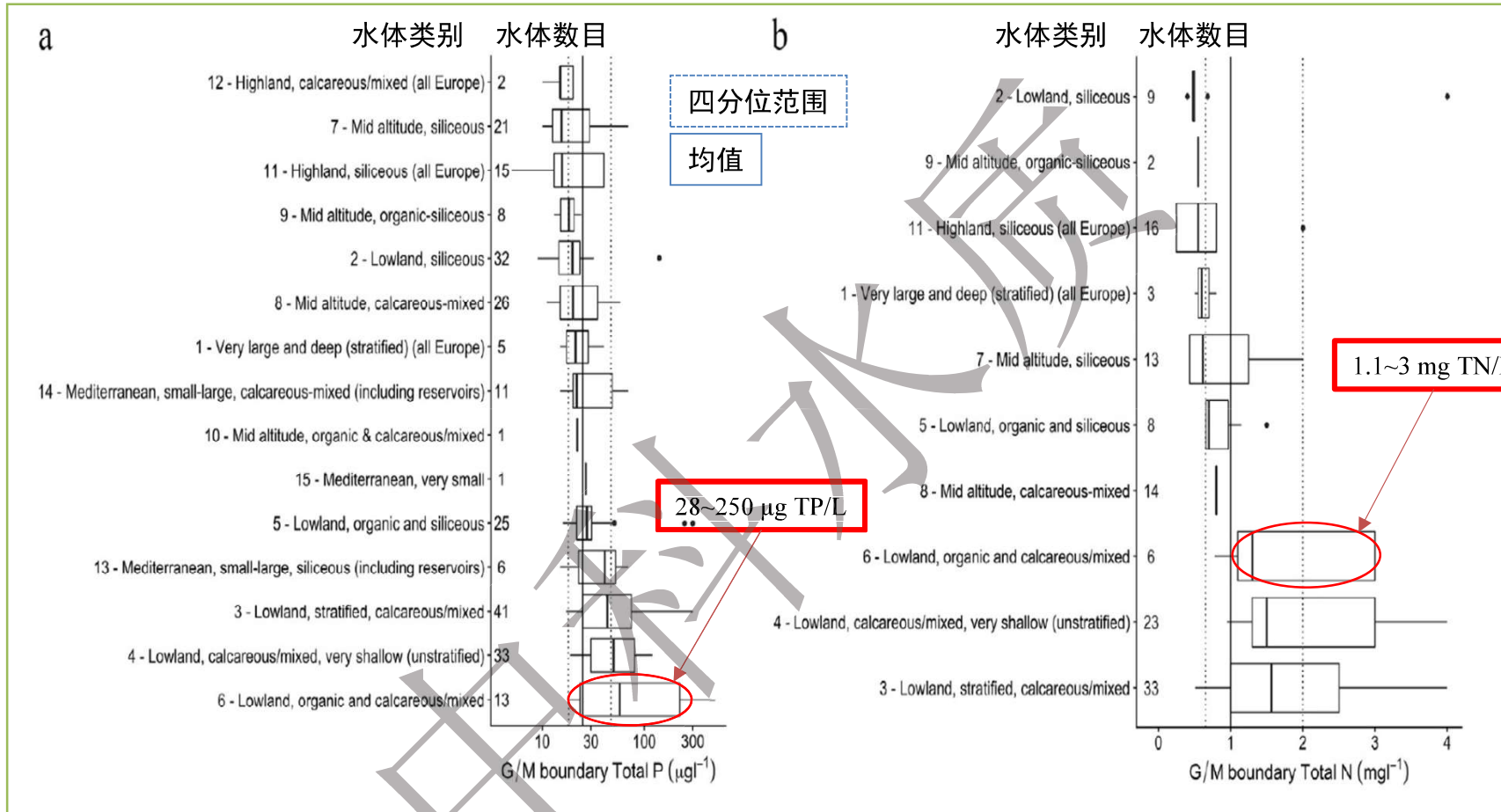
GM界限(EQR=0.58)



固定大型植物指数比(EQR)下高碱度-超浅湖泊(L-CB2类)水体TP或TN的界限

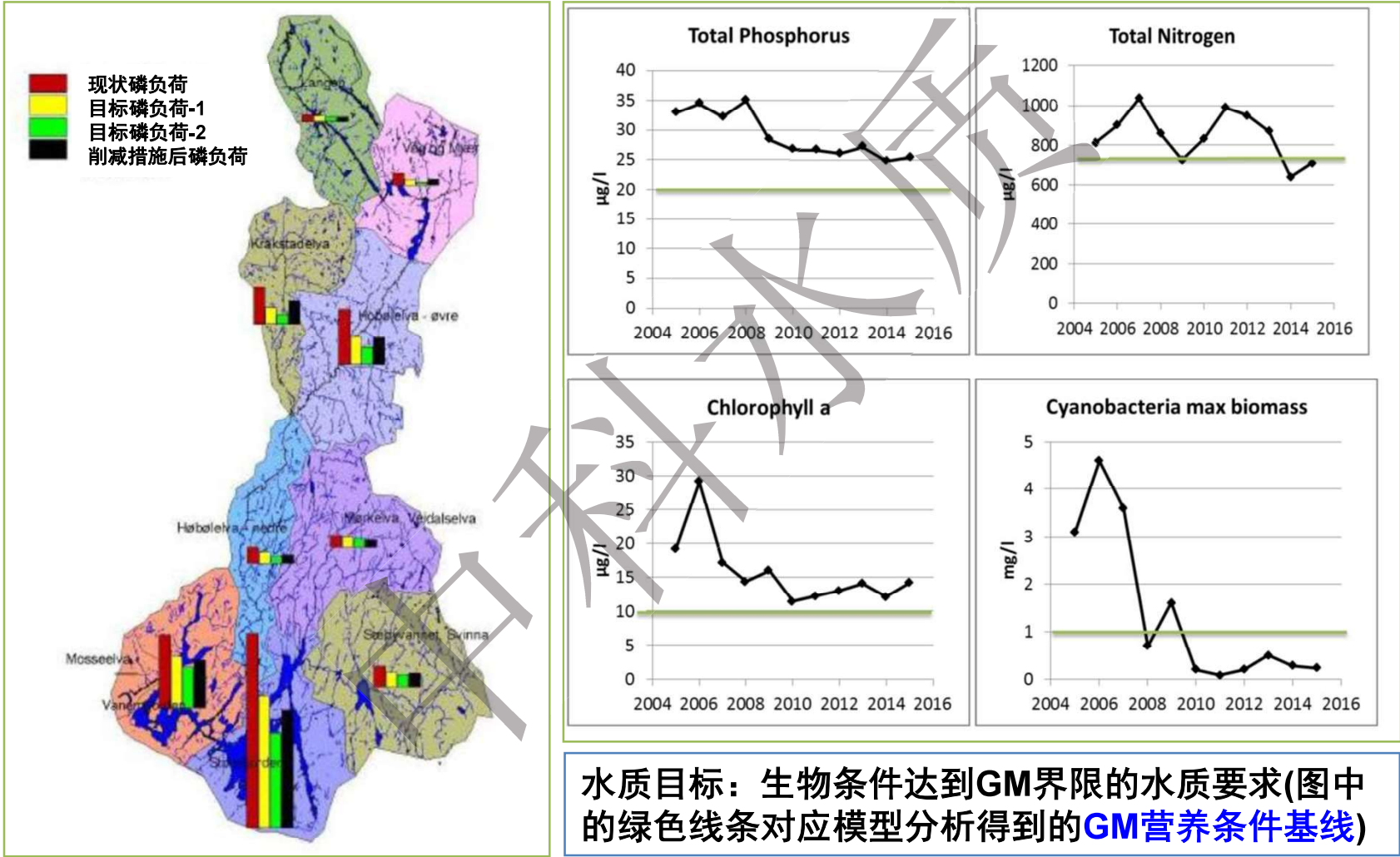
Relationship between mean TP and TN in high alkalinity very shallow lakes (L-CB2). Dotted lines show contours of predicted TN and TP concentration when macrophyte EQR is at a) high/good and b) good/moderate boundary (± 25 th & 75 th residuals of prediction). Horizontal and vertical lines show intersection with RMA regression of observed TP and TN showing good moderate boundary concentrations.

根据类别化后EQR得到欧盟成员国统一湖泊GM界限的氮、磷阈值(宽泛类别)



如图所示对湖泊水质产生影响的氮和磷浓度阈值与湖泊水体的海拔高度、面积、深度、碱度、有机质含量和分层现象之间的关系密切。低海拔地区富含有机质的石灰质基质地质构造的湖泊磷污染导致的问题最大；低海拔地区石灰质基质地质构造的浅水或分层或富含有机质湖泊氮污染导致的问题最大。较高的界限阈值通常采用参考条件由专家判别方式。(Sandra Poikane, 2019)

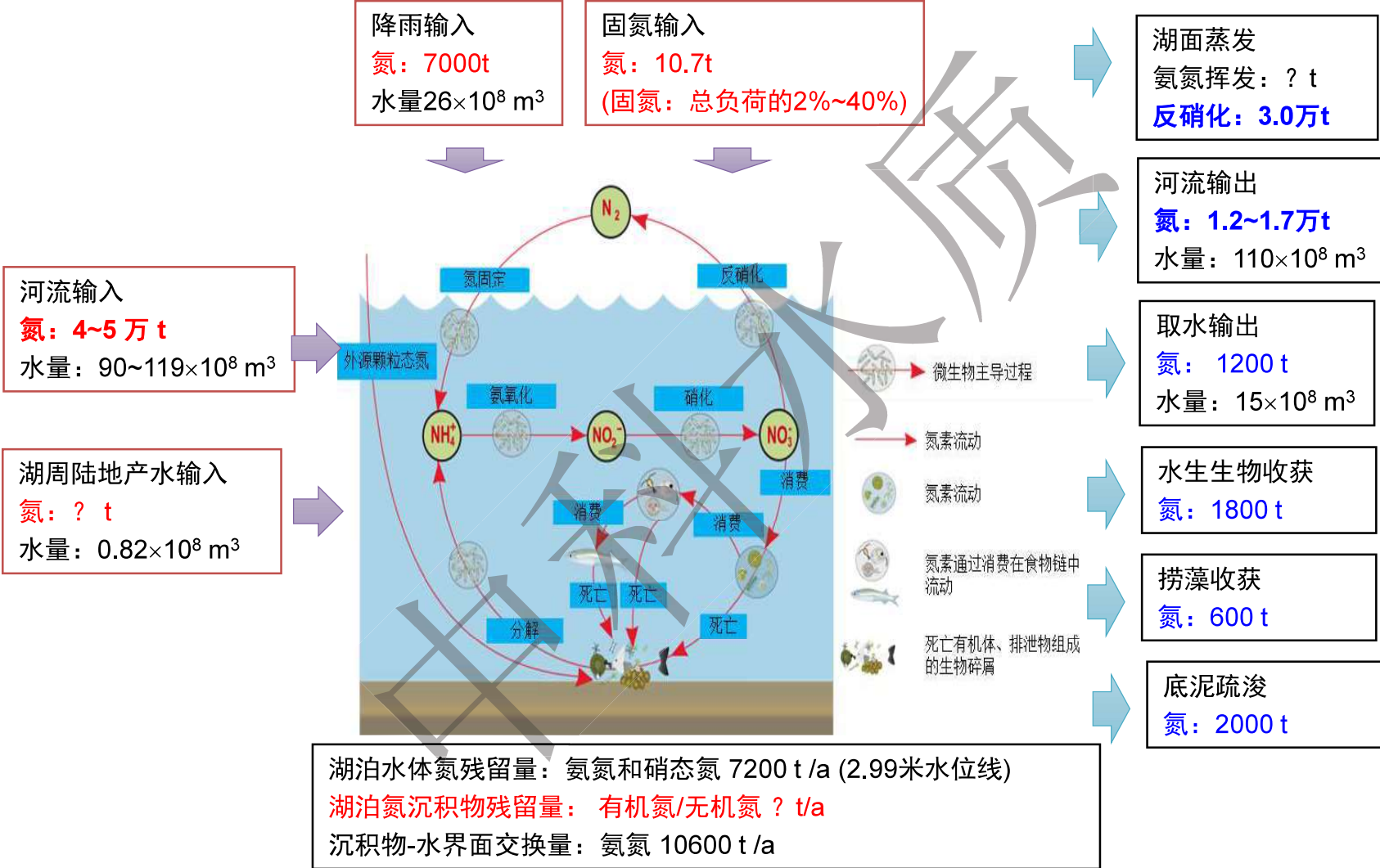
在挪威Vansjø湖小流域RBMP中生态状态目标值和营养盐负荷削减计划



关于中国湖泊富营养化控制的一点看法
(平衡净负荷的技术路线)

根据文献资料估算的太湖氮通量分析

Estimated flux level of nitrogen in Taihu Lake based on varies literatures



根据已经发表的文献数据整理（张亚平等，2016），太湖总氮的通量估算值有很大不确定性。

太湖磷的通量分析

Estimated flux level of phosphorus in Taihu Lake based on varies literatures



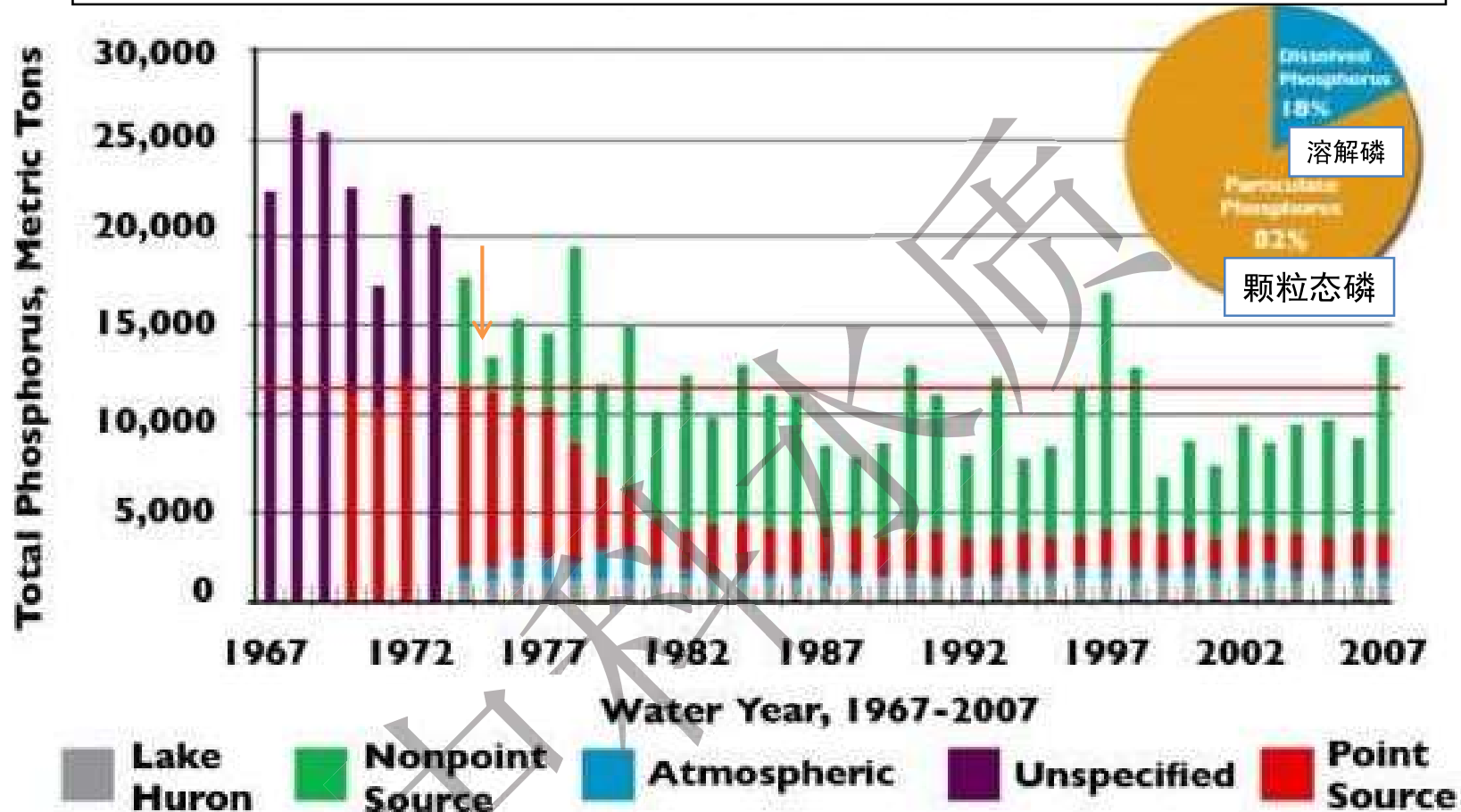
翟淑华等, 湖泊科学, 2014; 胡开明等, 湖泊科学, 2014; 马倩等, 湖泊科学, 2012; 易卷, 湖泊科学, 2016
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湖泊营养状态与磷负荷之间的关系分析(Vollenweider, 1973)

Mean Depth/Hydraulic Detention Time (meters/year)	Oligotrophic or Permissible Loading (grams/meter ² /year)	Eutrophic or Critical Loading (grams/meter ² /year)
0.5	0.07	0.14
1.0	0.10	0.20
太湖: 2m	0.16	0.32
滇池: 5m	0.22	0.45
7.5	0.27	0.55
洱海: 14m	0.32	0.63
伊利湖: 18m	0.50	1.00
50.0	0.71	1.41
75.0	0.87	1.73
100.0	1.00	2.00

现状负荷: 0.61~1.15 g/m²

通量削减率估算：伊利湖流域TMDL中营养盐的控制策略及成效



- 伊利湖的当前磷负荷大约 $0.97\text{t}/\text{km}^2$ 。初始输入量 25000t ，30年实际削减率为50%；
- 太湖的当前磷负荷大约 $1.02\text{t}/\text{km}^2$ 。初始输入量 2500t ，是伊利湖磷输入量的1/10，现状目标削减率需要 $>50\%$ ；
- 滇池的单位磷负荷大约 $1.08\text{t}/\text{km}^2$ 。初始输入量 360t ，大约是太湖磷输入量的15%，现状目标削减率需要 $>90\%$ (模型预测值)。

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