14 July 2004
Hokkaido University

Water Environment Regeneration in Urban Area and UV Disinfection Technology

OHGAKI, Shinichiro
The University of Tokyo

CONTENTS

1. Water Environment Regeneration in Tokyo
2. Waterborne Pathogenic Microbial Agents
3. Wastewater Reuse
   - categories and water quality criteria -
4. Ultraviolet Disinfection Technology and Photoreactivation

(Ohgaki, 2004)

CONTENTS

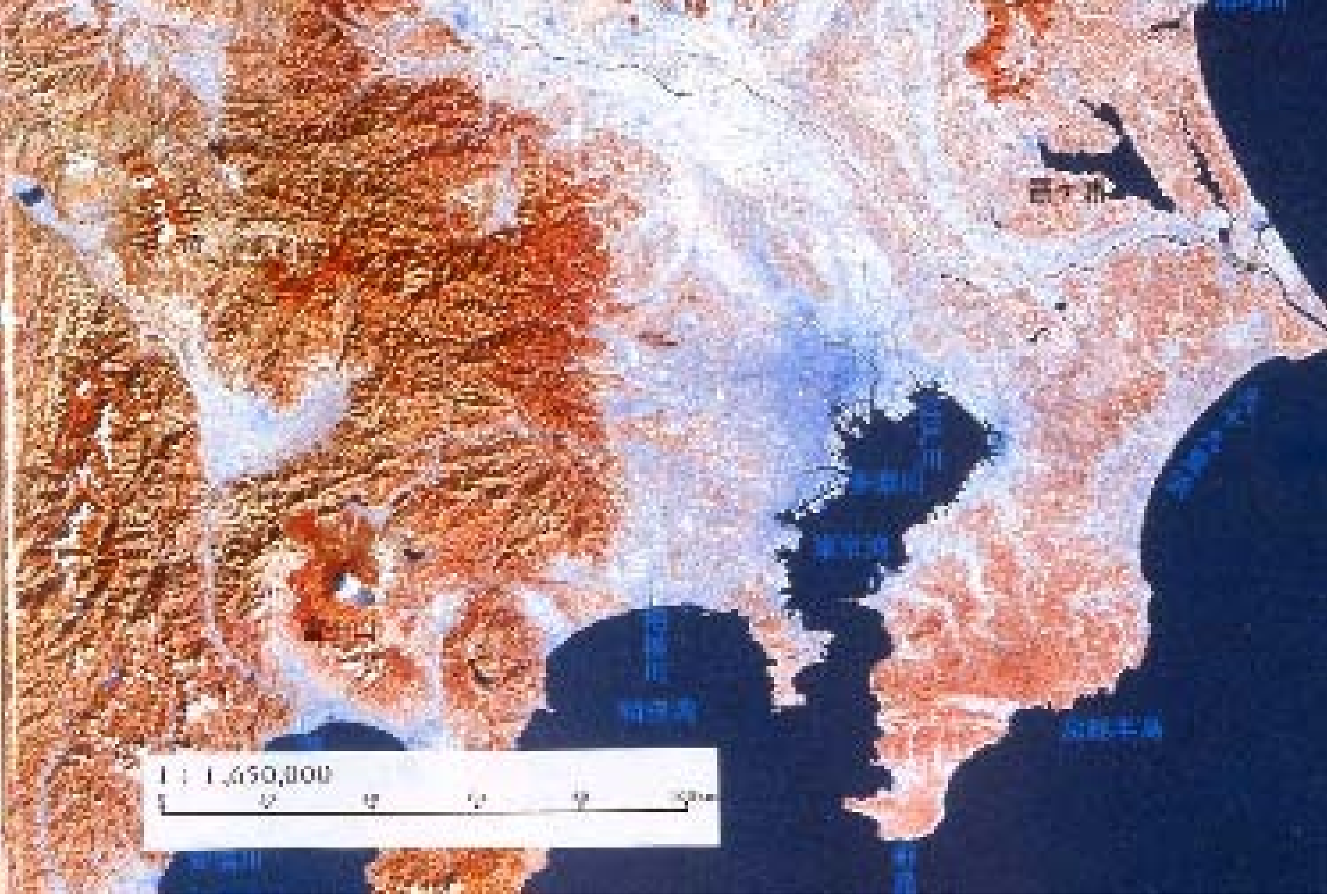
1. Water Environment Regeneration in Tokyo
2. Waterborne Pathogenic Microbial Agents
3. Wastewater Reuse

   - categories and water quality criteria -
4. Ultraviolet Disinfection Technology and Photoreactivation

Tokyo and surrounding urban area
as
a super mega city

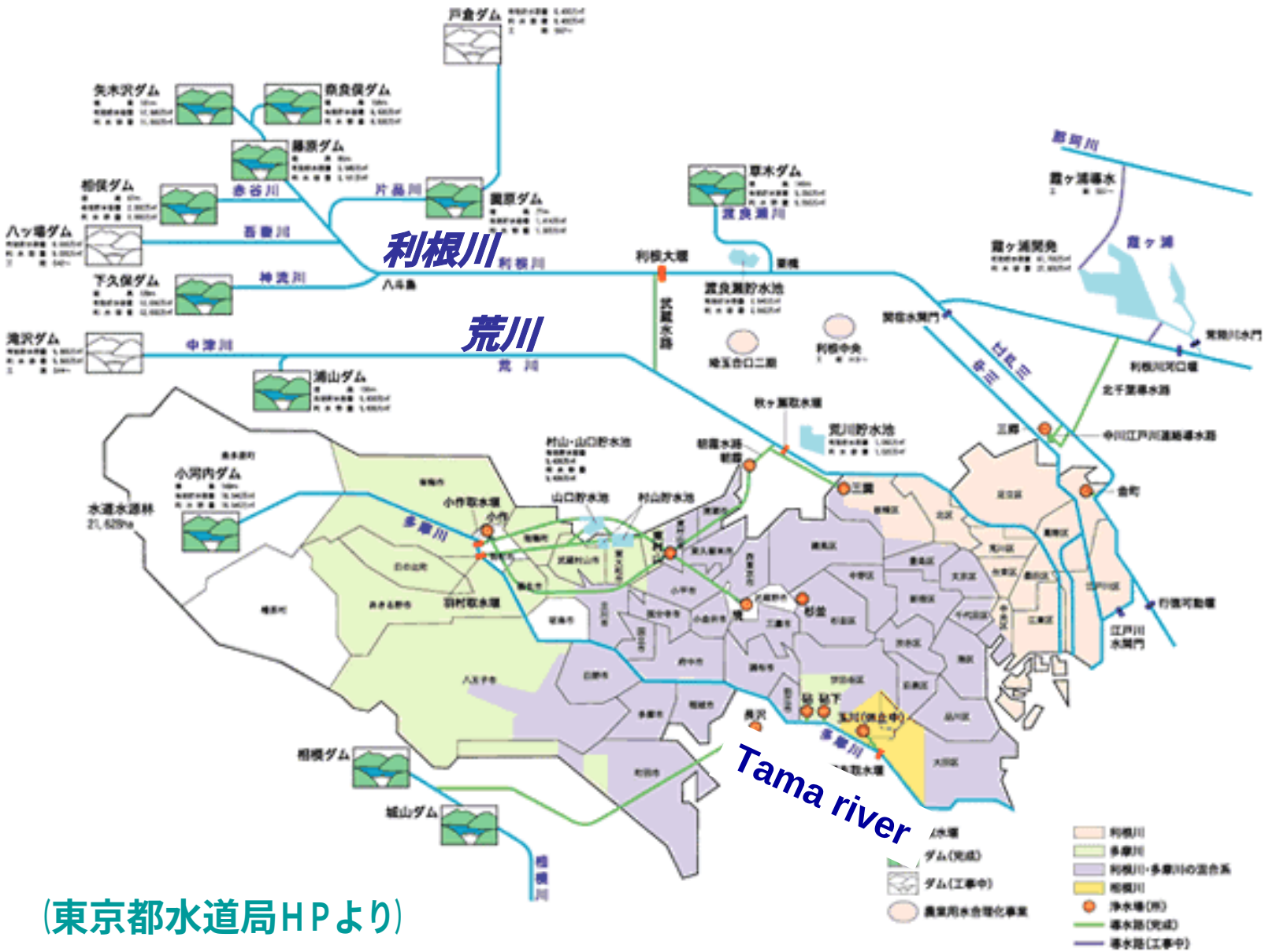
(population : around 30 million)

(Ohgaki, 2004)



(Ohgaki, 2004)

Water Resources for Tokyo



(東京都水道局ＨＰより)

神奈川県の水供給体制

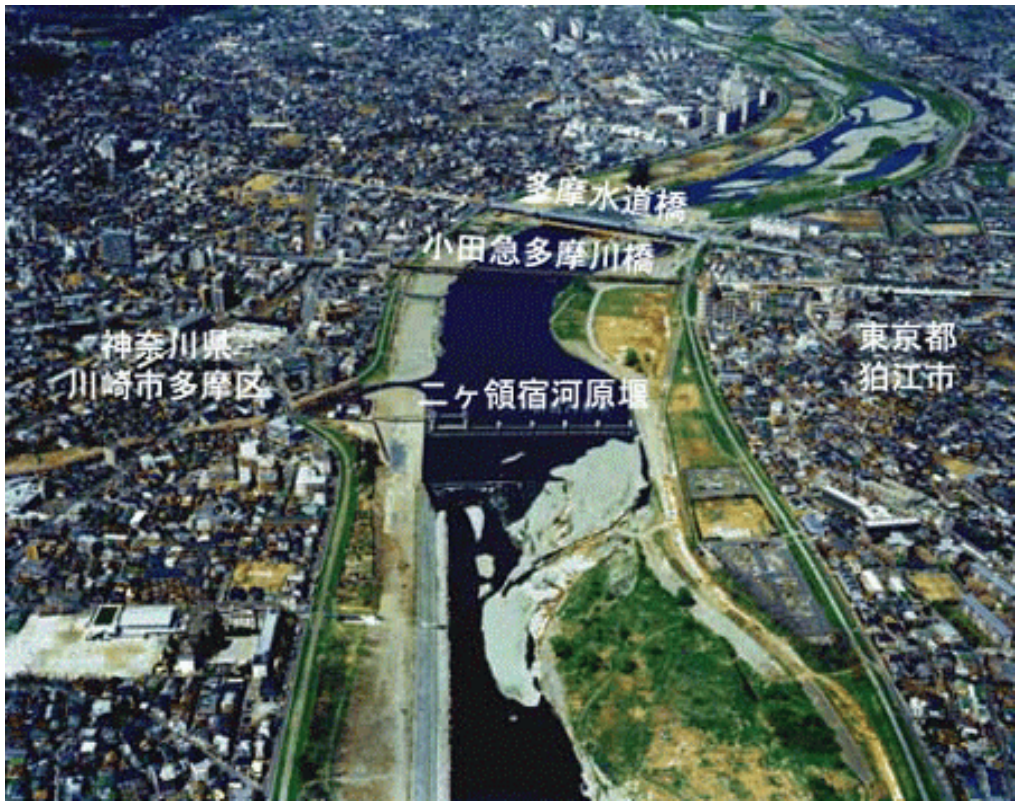
Kanagawa Pref.(population=8.7million)

KANAGAWA WATER SUPPLY AUTHORITY WEBSITE

原図：神奈川県内広域水道企業団ホームページより

(Ohgaki, 2004)

Tama River flows through Densely Inhabited Area

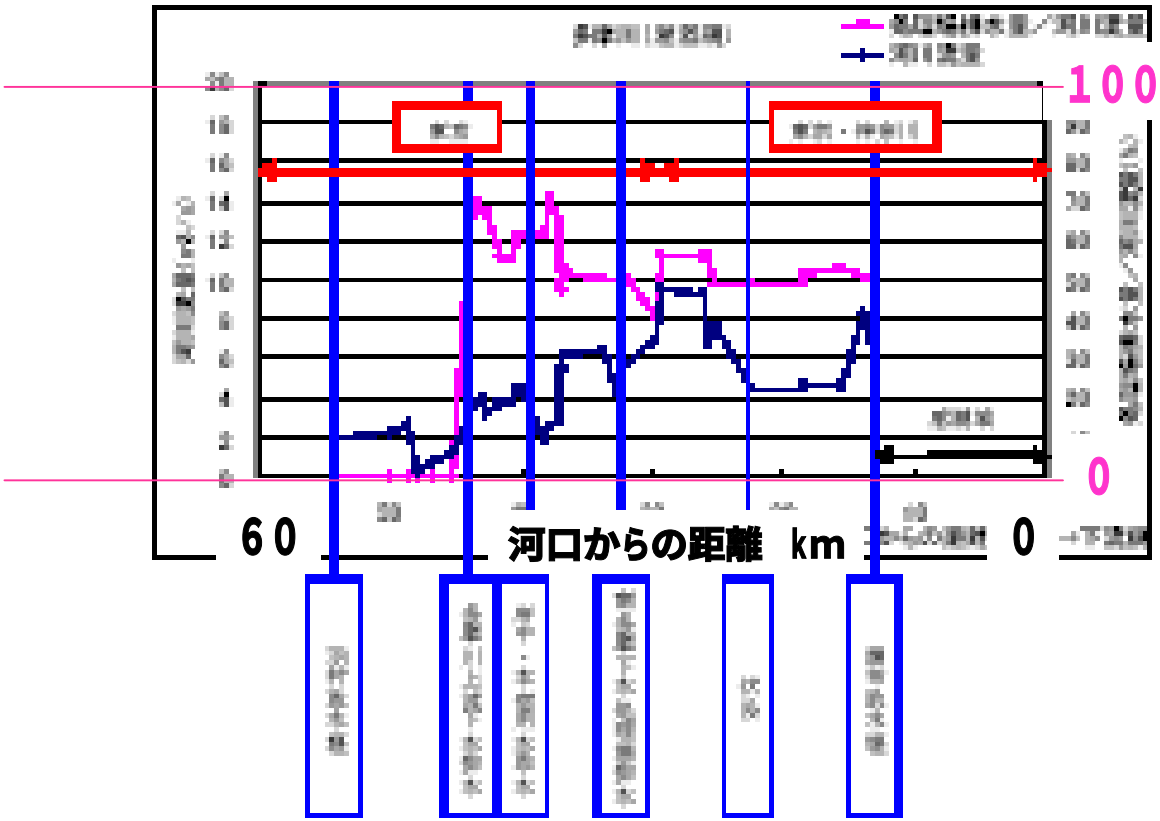


都市河川　多摩川の姿（河口から 22km地点）

（国土交通省　京浜工事事務所ホームページより）

(Ohgaki, 2004)

High ratio of Discharge from Sewage Treatment Plants in Flowrate of Tama River



Ratio of Discharge from Sewage Treatment Plants in Flowrate of Tama River

(東京都ホームページより)

(Ohgaki, 2004)

Reclaimed wastewater is supplied
to
Shinjuku skyscrapers
from
Ochiai sewage treatment
for
toilet flushing.

(Ohgaki, 2004)

(Ohgaki, 2004)

Shinjuku skyscrapers and Tokyo City Hall

Yodobashi Water Treatment Plant (slow sand filtration)
(operated until 1960's)

(Ohgaki, 2004)

Reclaimed wastewater for Ornamental reuse in Landscape regeneration

(Ohgaki, 2004)

(Translated from HP of Tokyo Metropolitan Authority)

(Ohgaki, 2004)

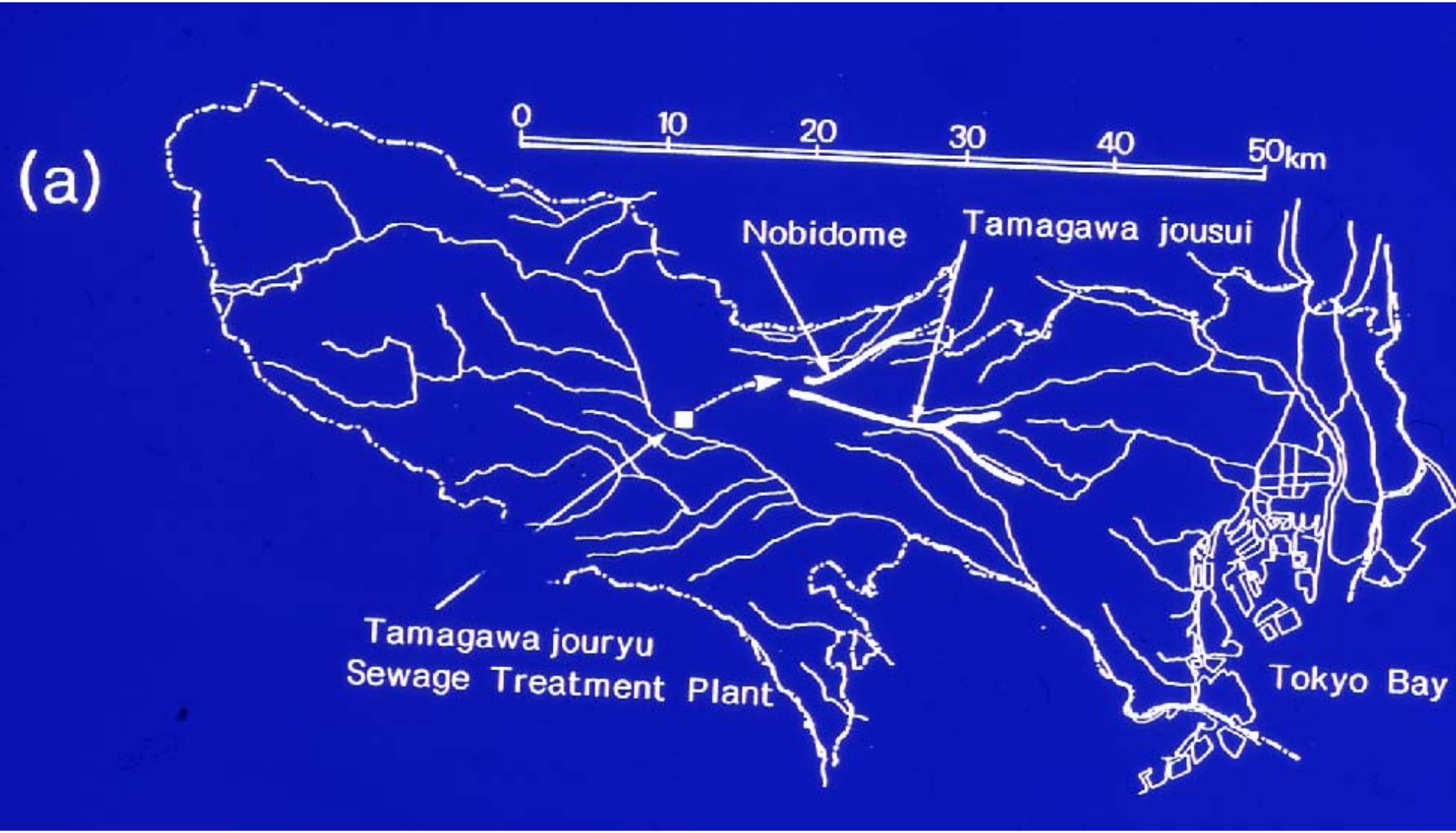
Tamagawa Joshui Channel

(東京都環境局パンフレットより)

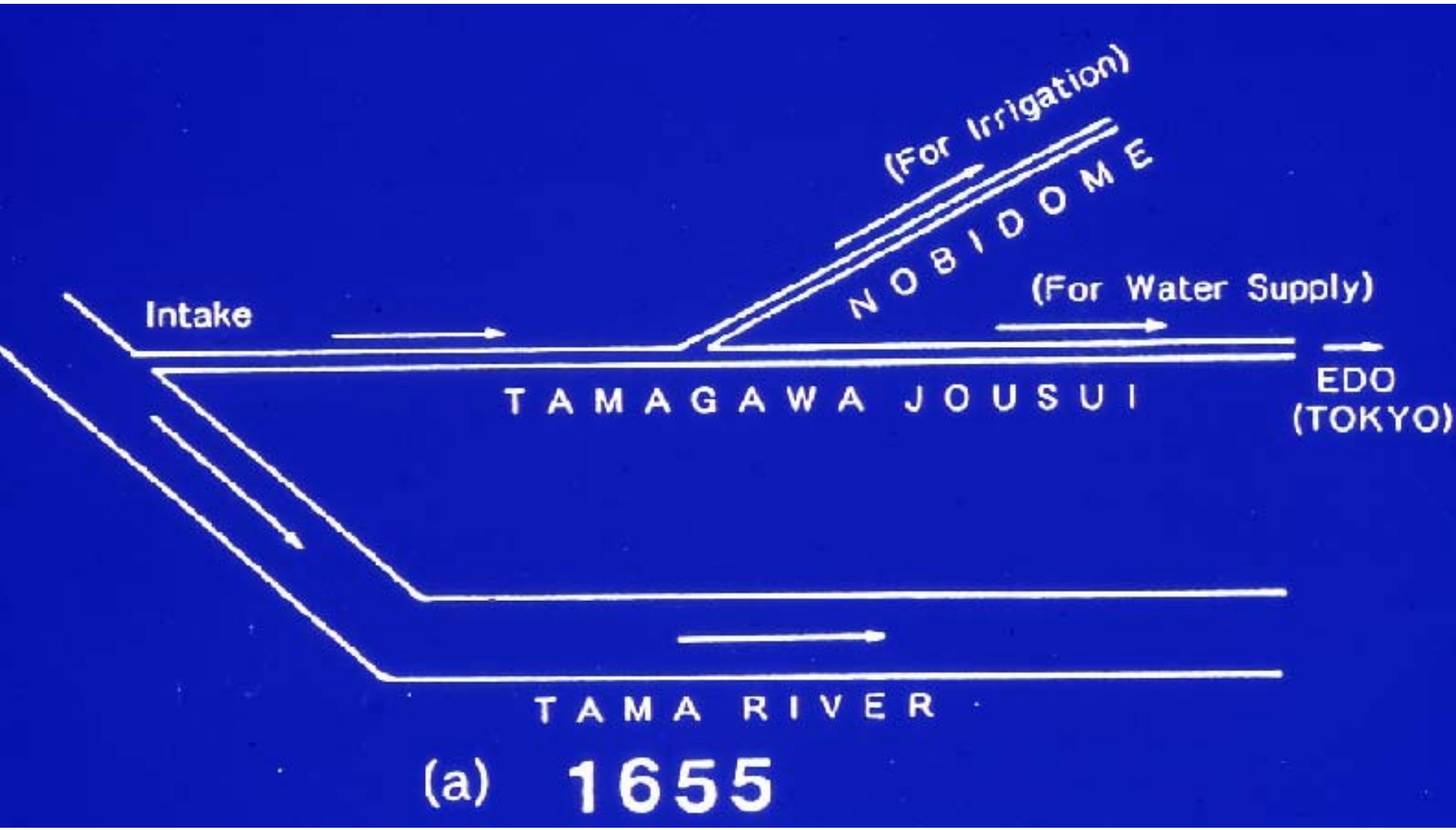
(Ohgaki, 2004)

(Ohgaki, 2004)

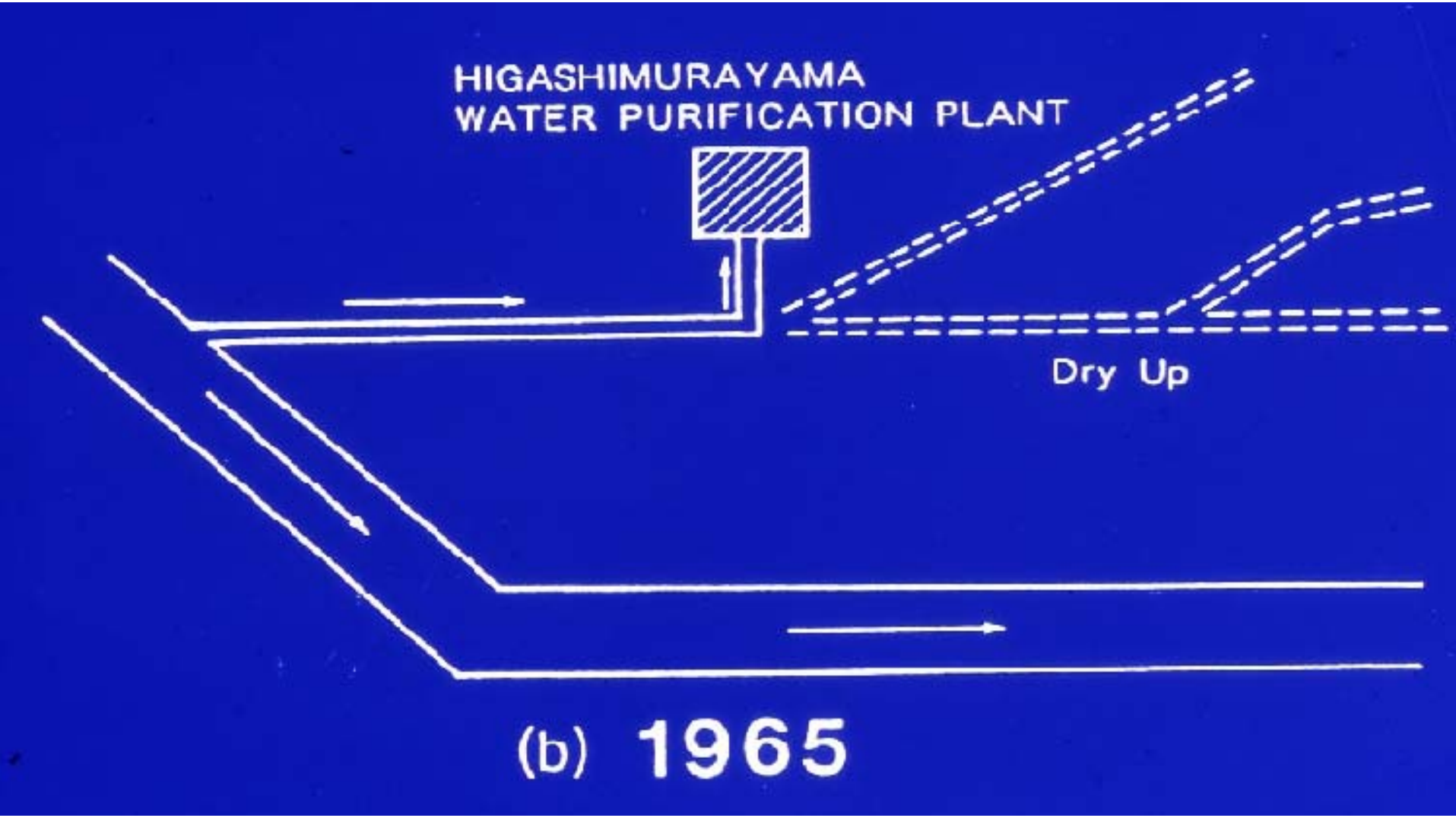
(Ohgaki, 2004)


(a)
0
10
20
30
40
50km
Nobidome
Tamagawa jousui
Tamagawa jouryu
Sewage Treatment Plant
Tokyo Bay

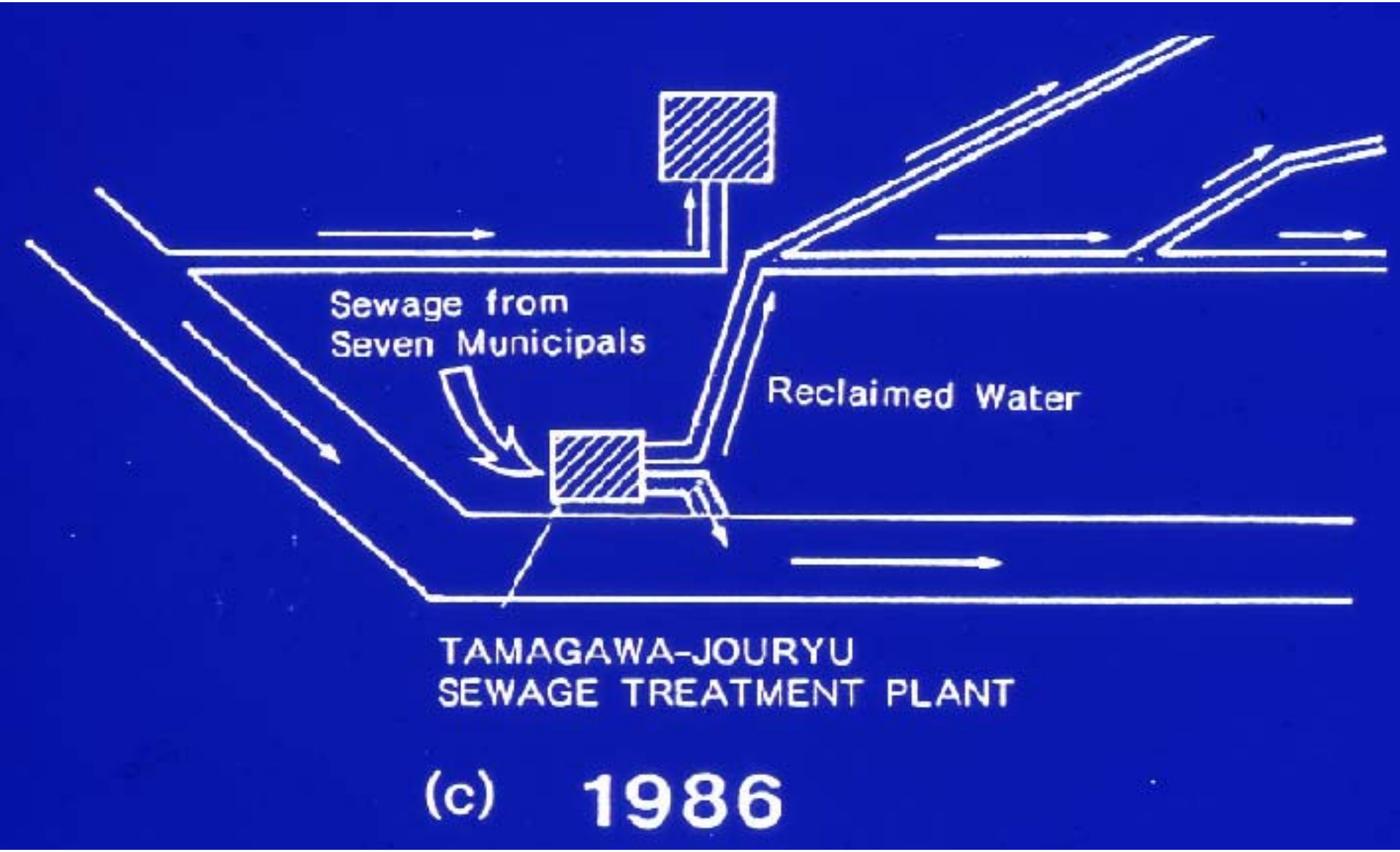
(Ohgaki, 2004)


(For Irrigation)
NOBIDOME
Intake
(For Water Supply)
EDO
(TOKYO)
TAMAGAWA JOUSUI
TAMA RIVER
(a) 1655

(Ohgaki, 2004)



(Ohgaki, 2004)


Sewage from
Seven Municipals
Reclaimed Water
TAMAGAWA-JOURYU
SEWAGE TREATMENT PLANT
(c) 1986

(Ohgaki, 2004)

Questions Arisen

-What kind of water quality required ?

-Who has the responsibility ?

-What kind of techniques is applied

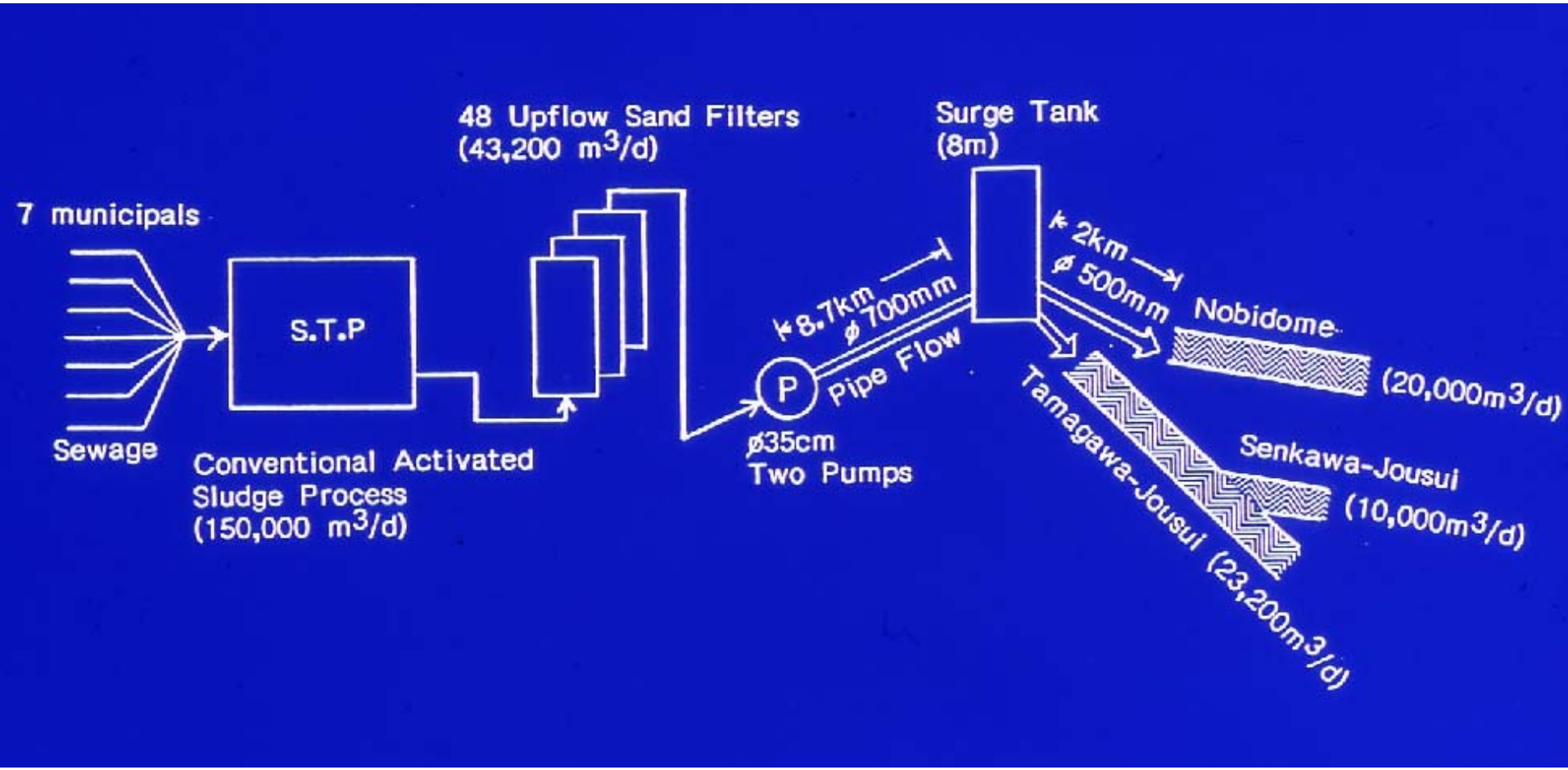
for the management and operation ?

-What is the social benefit?

-Why is the cost for only ornamental

purposes accepted by the public?

(Ohgaki, 2004)


48 Upflow Sand Filters
(43,200 m3/d)
Surge Tank
(8m)
7 municipals
S.T.P
8.7km
ϕ 700mm
Pipe Flow
2km
ϕ 500mm
Nobidome
(20,000m3/d)
Sewage
Conventional Activated
Sludge Process
(150,000 m3/d)
P
ø35cm
Two Pumps
Tamagawa-Jousui (23,200m3/d)
Senkawa-Jousui
(10,000m3/d)

(Ohgaki, 2004)

(Ohgaki, 2004)

(Ohgaki, 2004)

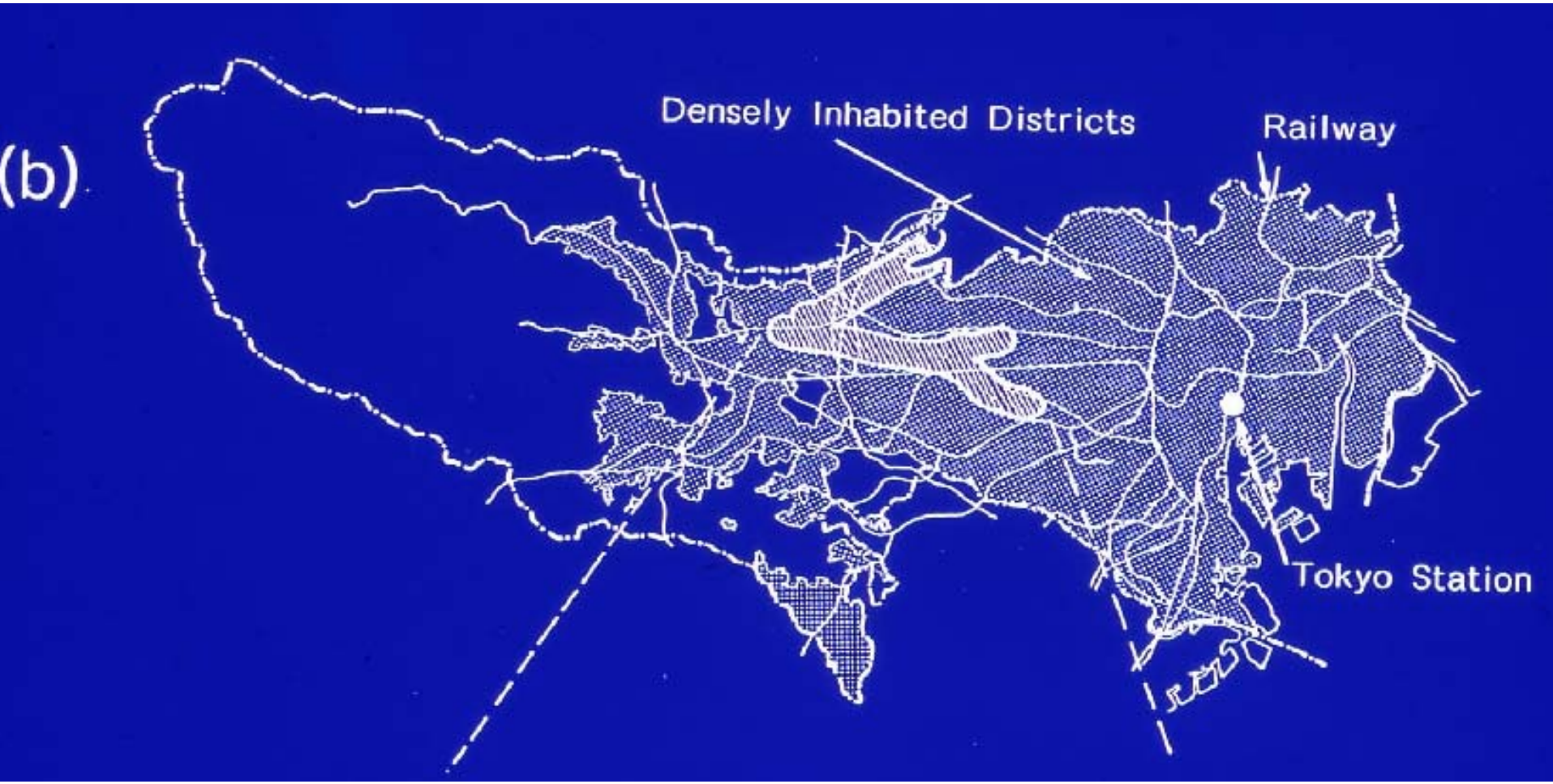
Special Management and Operation

Foaming: Silicone Antifoaming Reagent (When Necessary)

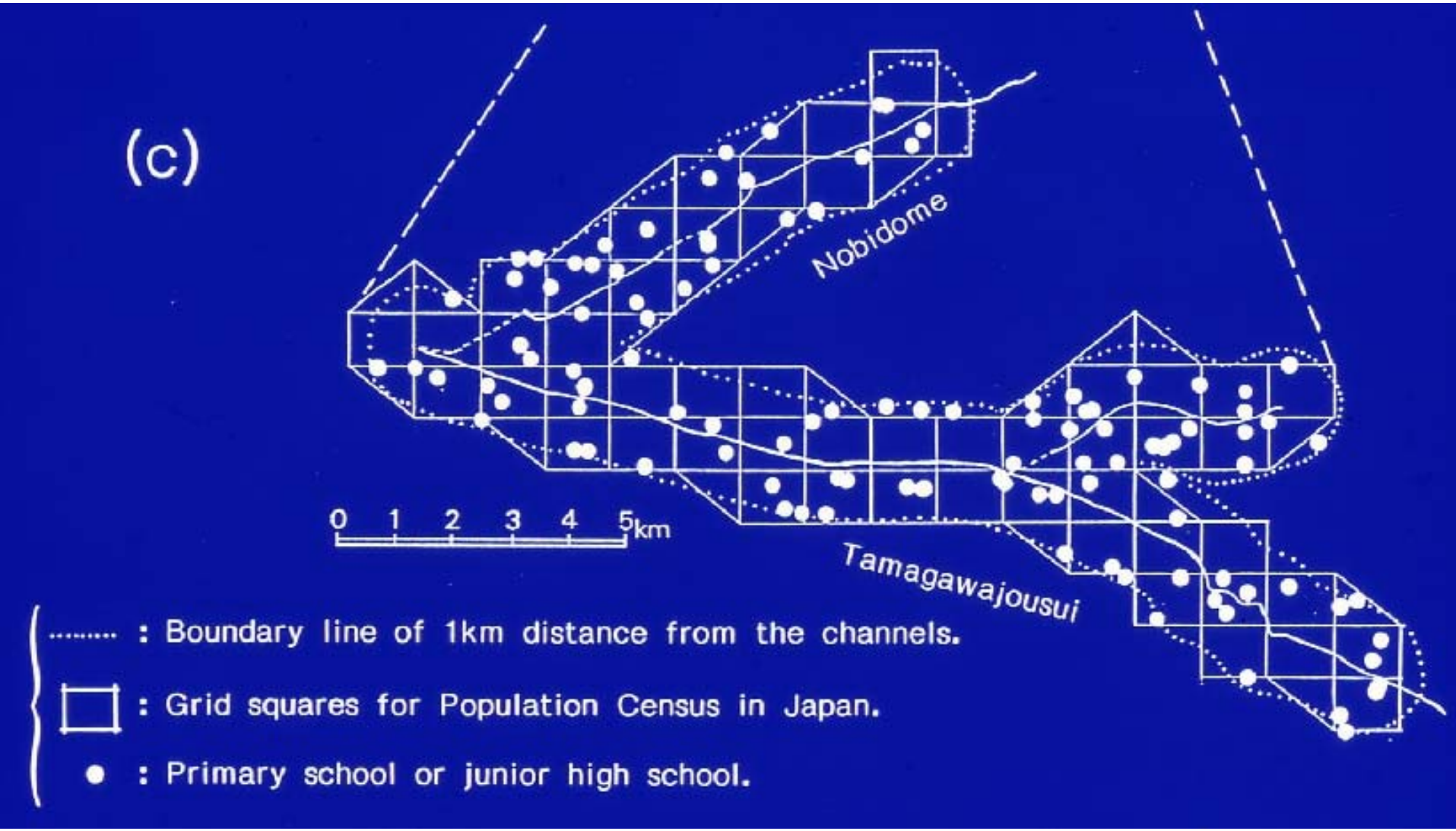
Midges : - To Stock Fishes
- Insects Growth Regulating Substance

Odor : Ozone Treatment (Under construction)

(Ohgaki, 2004)



(Ohgaki, 2004)


(c)
Nobidome
Tamagawajousui
0 1 2 3 4 5km
..... : Boundary line of 1km distance from the channels.
: Grid squares for Population Census in Japan.
: Primary school or junior high school.

(Ohgaki, 2004)

In the Neighborhood 1Km Distance from the Channels

Population	- 0.64 Million
Population Less Than 14 Years Old	- 0.12 Million
Primary And Junior High School	-108 Schools

(Ohgaki, 2004)

Seawater reclamation facility with UV radiation for water quality improvement at Tokyo bay seashore

(Ohgaki, 2004)

Odaiba seashore and the outlet of reclaimed seawater in a pilot study

お台場海浜公園

（東京都環境局ＨＰ）

(Ohgaki, 2004)

お台場海浜公園における海域浄化実験 (東京と下水道局)

図１３海域浄化実験全体配置

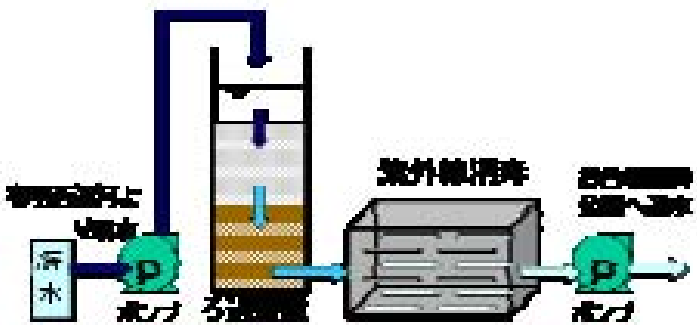


図１４　海水浄化プラントフロー図

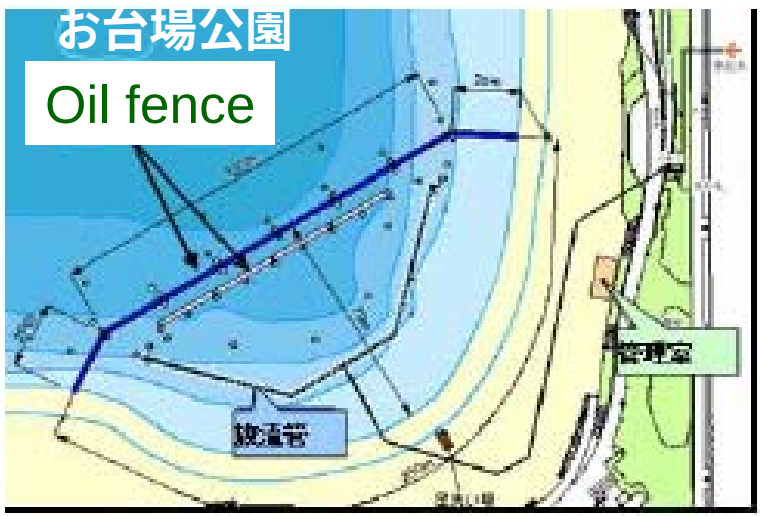


図１５　浄化エリア配置図

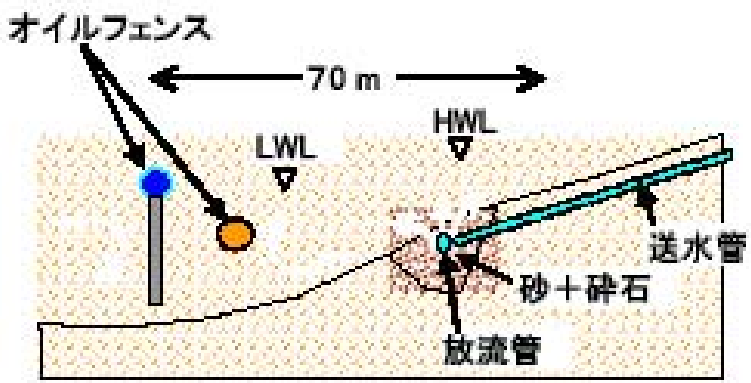


図１６　オイルフェンス仕切断面図

Seawater Treatment Facility with UV at Tokyo Bay Searshore (Started from July 2003)

(Oguma and Ohgaki,2003)

Discharge

Ariake Canal

pumped up

Bio-membrane filtration

UV disinfection

Medium-pressure UV lamps (1.9kW×12)

effluent

(5000m3/d)

(Photo by Masago June 2003)

(Ohgaki, 2004)

Seawater Treatment Facility with UV at Tokyo Bay Seashore

Ariake WWTP discharges its treated water into Ariake Canal, where seawater is pumped up into the seawater treatment facility with UV disinfection process. The canal water flows into Odaiba seashore.

Odaiba seashore is a popular place to visit for walking around and even for bathing.

This facility was just started from this July, 2003 experimentally, and the water quality at Odaiba seashore has been investigated to test the effectiveness of the facility.

(Oguma, Masago and Ohgaki,2003)

(Ohgaki, 2004)

CONTENTS

1. Water Environment Regeneration in Tokyo
2. Waterborne Pathogenic Microbial Agents
3. Wastewater Reuse

    - categories and water quality criteria -

4. Ultraviolet Disinfection Technology and Photoreactivation

(Ohgaki, 2004)

水を経由してヒトに感染する病原微生物

ウイルス　(0．025－0．1μm)

A型肝炎ウイルス、E型肝炎ウイルス、
ノルウォークウイルス、　・・・・・

細菌　(1－10μm)

赤痢菌、コレラ菌、病原大腸菌、
レジオネラ菌、　・・・・・

原虫　(5－20μm)

クリプトスポリジウム、ジアルジア

(Ohgaki, 2004)

Representative Waterborne Infectious Agents

VIRUS (20-100nm):	
Enteroviruses	Paralysis, meningitis, respiratory illness, myocarditis, gastroenteritis, infectious hepatitis
Norovirus	Gastroenteritis
:	
BACTERIA(1-10µm):	
Shigella	Bacillary dysentery
E.Coli O157:H7, and other serogroups	Dysentery,hemolytic uremic syndrome,gastroenteritis
Legionella pneumophila	Legionnaries' Disease, Pontiac Fever
:	
PROTOZOA(5-20µm):	
Giardia lamblia	Diarrhea
Cryptosporidium parvum	Gastroenteritis, flu-like symptoms to severe illness
:	

(Ohgaki, 2004)

クリプトスポリジウム
(Cryptosporidium parvum)

過去に起きた飲料水由来の大きな事故

- **米国Wisconsin州 Milwaukee (1993年)：約40万人が発症**
- **埼玉県越生町 (1996年)：8000人以上が発症**

クリプトスポリジウム オーシスト (直径約5 μm)

(国立感染症研究所寄生動物部ホームページより)

(Ohgaki, 2004)

海域で問題となる主な腸管系ウイルス

- Enterovirus
  - 大きさ：約30nm
  - 夏のプール・海での下痢症の主な原因
- Norovirus
  - 大きさ：約30nm
  - 形体により小型球形ウイルス（SRSV）に分類されるウイルスのほとんどがNorovirus
  - ウイルス性食中毒の9割
  - カキによる食中毒の主原因

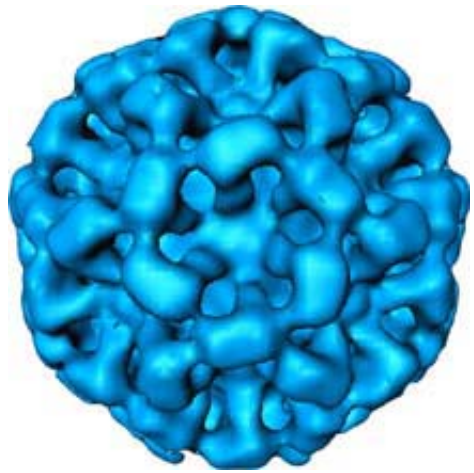

小型球形ウイルス（SRSV）

：海水中のＳＲＳＶがカキ等の中腸腺に取り込まれ（カキは１日に２４Ｌ～７０Ｌの海水を取り込む）、これを食べることにより感染し発症。ＳＲＳＶ感染者やＳＲＳＶに汚染された水・調理器具を介して感染することもある。

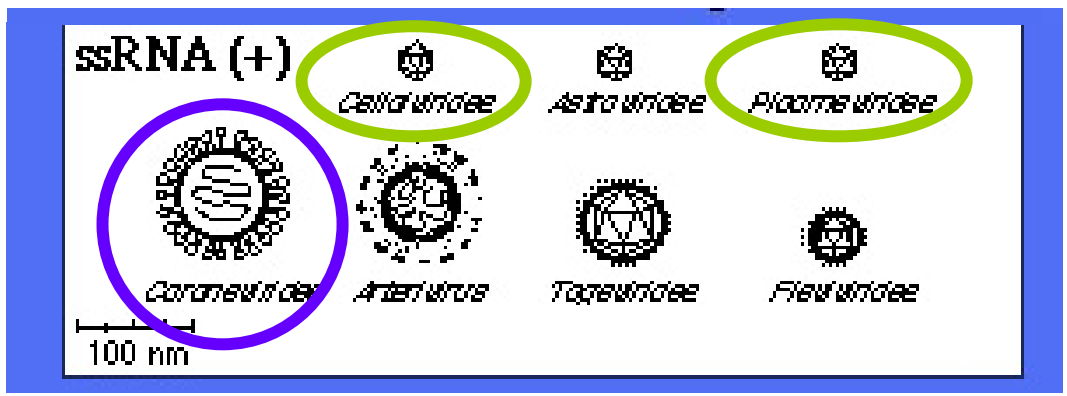
(Ohgaki, 2004)

海水浴場での腸管系ウイルスの検出

- エンテロウイルス
  - 大きさ：約30nm
  - 夏のプール・海での下痢症の主な原因
- ノロウイルス
  - 大きさ：約30nm
  - カキ食中毒の原因
  - ウイルス性食中毒の9割
- 測定方法
  - 海水からRNAを抽出
  - PCRで遺伝子を増幅
  - 配列を解読して判定



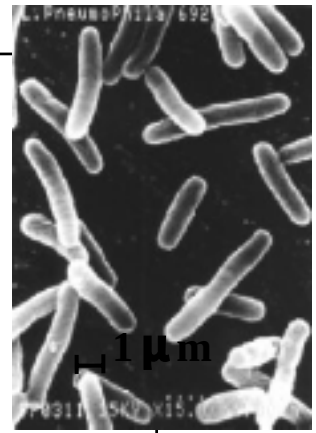
ノロウイルス



(Ohgaki, 2004)

(2003、片山、真砂、東京大学 大学院)

Background of Legionella pneumophila



- A pathogenic bacterial strain
- Causes legionellosis:
  - Legionnaries' Disease (fatal with severe pneumonia: 95%)
  - Pontiac Fever (influenza-like illness for 2-5days: 5%)
- Many waterborne outbreaks through an aerosol form
- Resistant to chemical disinfectants mainly because of the association with biofilms
- More UV sensitive than coliforms

  →*UV system installation at point of use is recommended*

➡ Repair of *L. pneumophila* is an important issue.

(Photo: http://www.tokyo-eiken.go.jp/)

(Oguma,2003)

(Ohgaki, 2004)

Legionella outbreaks in Japan-1

Ex.1: A case at a local public bath, 2000, Ibaraki Pref.

- 18 *Legionella* spp. Including serogroup 1 were detected or cultured from the bath water, water filtration parts, filtrated water, and swab on mist sauna.
- In the facility, one of two water supply systems had no disinfection process. Bath water was scarcely changed, and water supply was insufficient. *(Reported by Mashiko et al.; Ibaraki Prefectural Institute of Public Health)*

Ex.2: A case at a spa resort with a water circulating system, 2000, Shizuoka Pref.

(Reported by Sugiyama et al.; Shizuoka Institute of Environment and Hygiene)

Ex.3: A case at a bathtub with an all day circulating system, 1999, Nagoya City

- *L. pneumophila* serogroup 6 was detected by PCR and antibody method from a bathtub with an all day circulating at a hospital.

(Reported by Nagai et al.; National Institute of Infectious Diseases)

(Ohgaki, 2004) (Oguma)

Legionella out breaks in Japan-2

Legionella pneumophila
(http://www.tokyo-eiken.go.jp/)

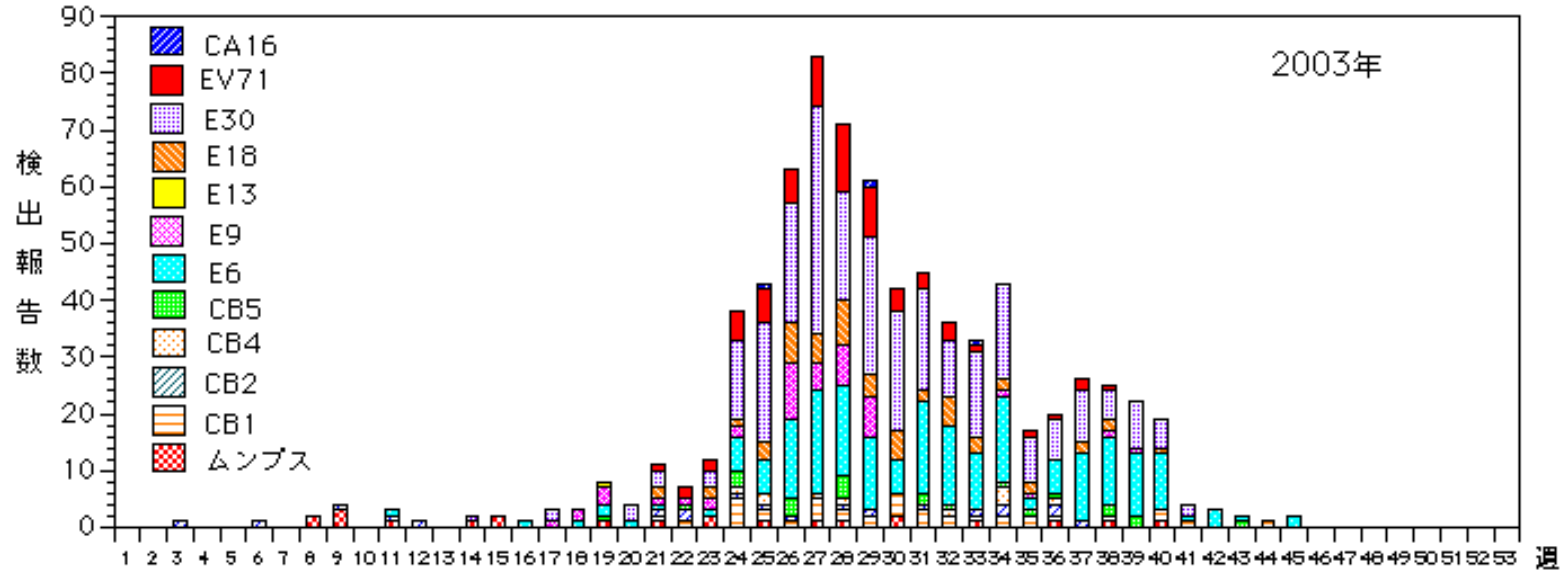
Legionellosis outbreaks in Japan are mostly associated with contaminated bathing water at public/home bath facilities with water circulating systems.

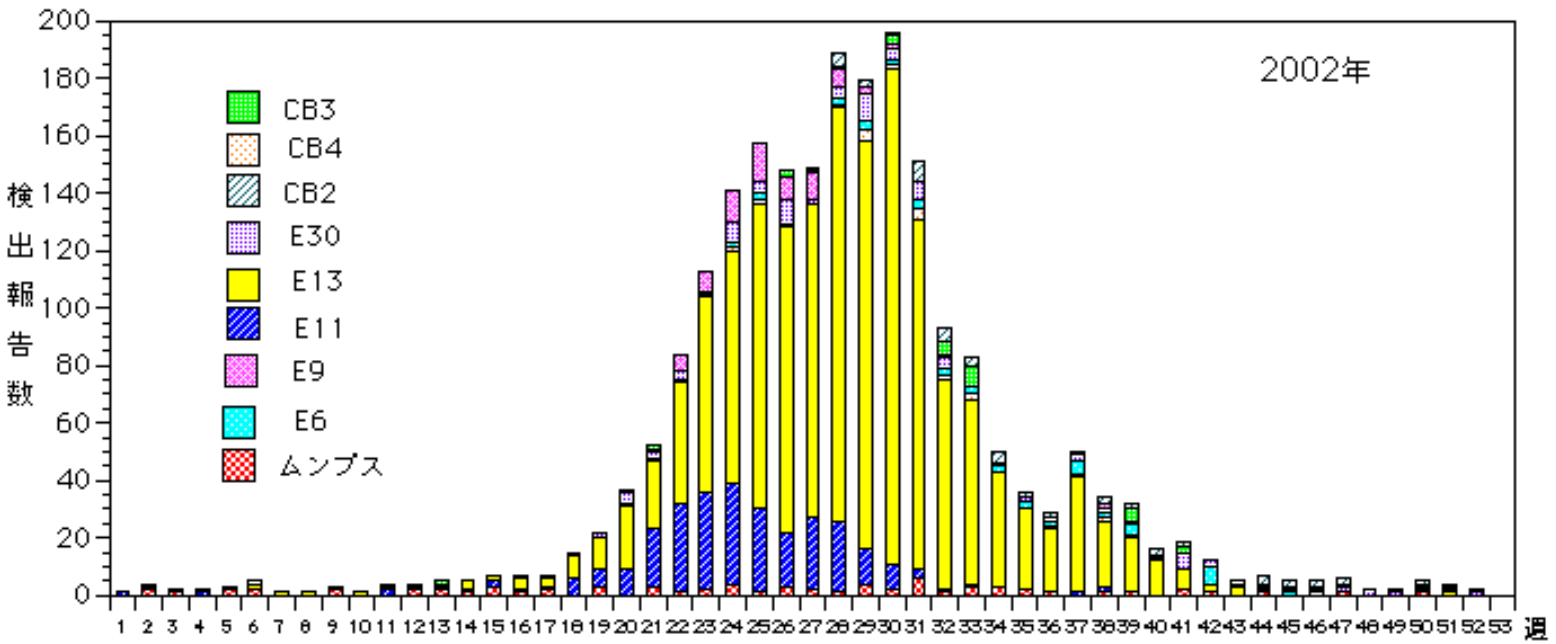
The all day circulating systems, or so-named "24hrs' bath", have decreased in number in last several years.

(Oguma)

(Ohgaki, 2004)

Detection of Enterovirus from Cases in Japan

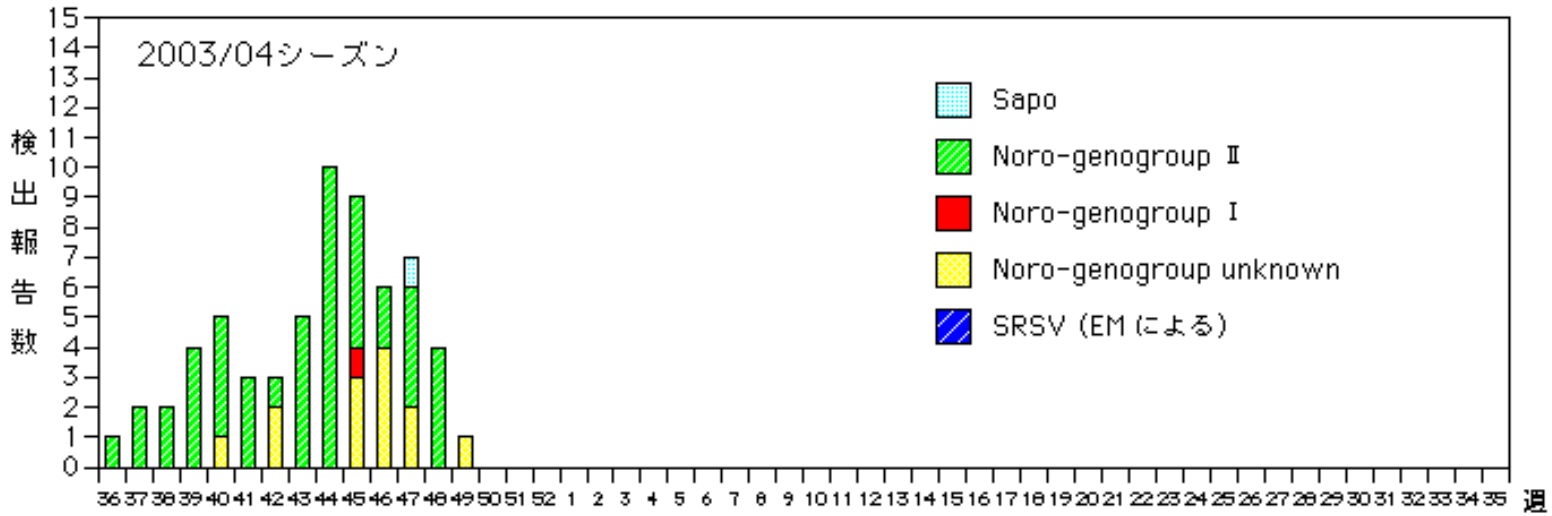


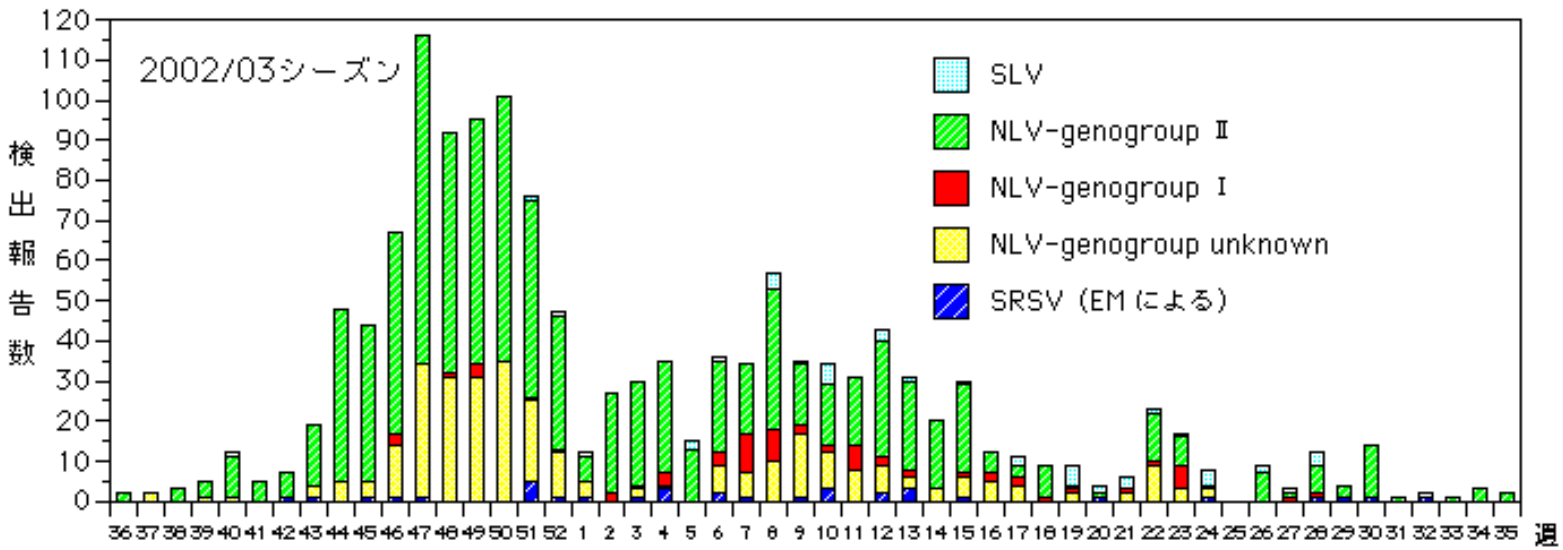


(Ongaki, 2004)

全国の地方衛生研究所からの報告数（2003年12月11日現在）

Detection of Norovirus from Cases in Japan





全国の地方衛生研究所からの報告数（2003年12月11日現在）

CONTENTS

1. Water Environment Regeneration in Tokyo
2. Waterborne Pathogenic Microbial Agents
3. Wastewater Reuse

    - categories and water quality criteria -

4. Ultraviolet Disinfection Technology and Photoreactivation

Wastewater reuse

- Categories

- Water quality criteria and guideline

(Ohgaki, 2004)

Categories of Municipal Wastewater Reuse

- Agricultural irrigation
- Landscape irrigation
+Industrial recycling and reuse
- Groundwater recharge
+Recreational/environmental uses
+Nonpotable urban uses
- Potable reuse

(Ohgaki, 2004)

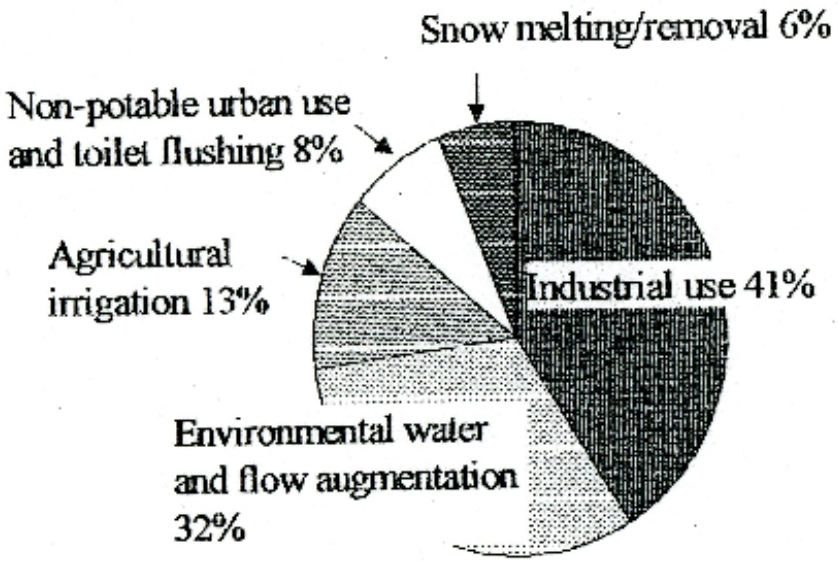
Reclaimed wastewater of Kobe city is supplied to the island

(Ohgaki, 2004)

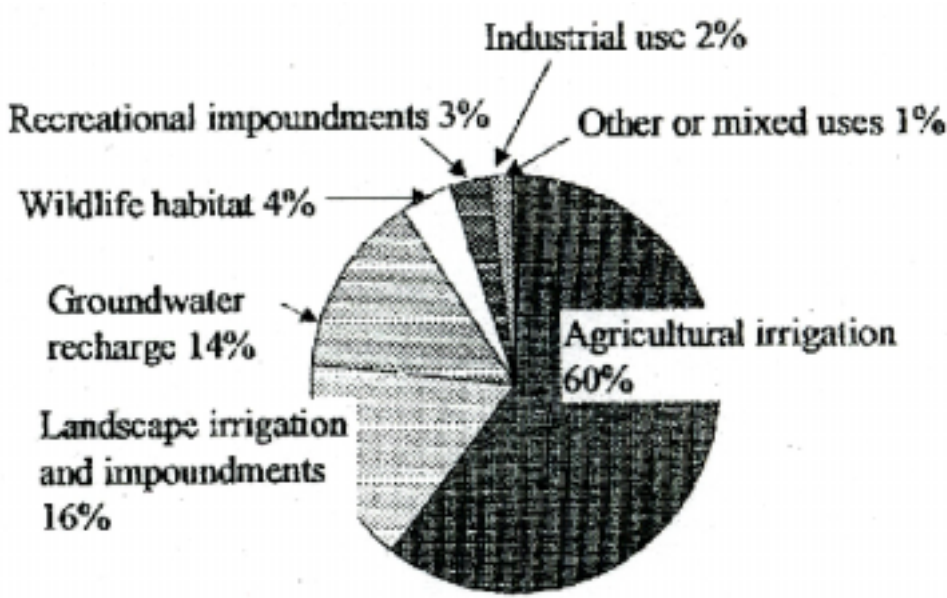
Reclaimed wastewater for a pond in a Japanese garden in Chiba Pref.

(Ohgaki, 2004)

Types and Volume of Wastewater Reuse in Japan and California



Japan
100* 10 ^{6} m^{3}/year



California
432*10^{6} m^{3}/year

(Asano et al.)

(Ohgaki, 2004)

Water Quality Guideline Manual

Reuse mode (Two Categories)

-Ornamental Reuse For Scenery:
Without Assuming Human Contact

-Recreational Reuse With Close Contact :
With Assuming Human Contact

(Ohgaki, 2004)

Water Quality Criteria for Reclaimed Water

	Parameters	Toilet flush water	Landscape irrigation	Ornamental water
Criteria	Coliform bacteria (count / ml)	<10	Not detected	Not detected
	Residual chlorine (combined, mg/l)	Retained *	>0.4	-
Guidelines	Appearance	Not unpleasant	Not unpleasant	Not unpleasant
	Turbidity (unit)	-		<10
	BOD (mg/l)	-		<10
	Odor	Not unpleasant	Not unpleasant	Not unpleasant
	pH	5.8-8.6	5.8-8.6	5.8-8.6

* Retained at the last holding tank in the distribution line.

(Ohgaki, 2004)

Water Quality Guidelines for ornamental and Recreational Reuse (Tentative)

Water Quality Item	Ornamental Reuse for Scenery	Recreational Reuse with Close Contact
Total Coliform	<1000 MPN/100ml	<50 MPN/100ml
BOD	<10 mg/l	<3 mg/l
PH	5.8-8.6	5.8-8.6
Turbidity	<10 unit	<5 unit
Odor	Not unpleasant	Not unpleasant
Color	<40 unit	<10 unit

(Ohgaki, 2004)

Water Quality Criteria for Coastal Water used for Bathing Recreation

Category		Fecal Coliform	Oil Slick	COD	Transparency
Recommended	AA	Not detected 2/100ml	Not detected	2mg/L and below	1m and over
	A	100/100ml and below	Not detected	2mg/L and below	1m and over
Acceptable	B	400/100ml and below	Detected in unusual case	5mg/L and below	1m～50cm
	C	1000/100ml and below	Detected in unusual case	8mg/L and below	1m～50cm
Not acceptable		More than 1000/100ml	Detected	More than 8mg/L	Less than 50cm

(Ohgaki, 2004)

(Ministry of Environment.1997)

State of California wastewater reclamation criteria for irrigation and recreational impoundments

Use of reclaimed wastewater	Description of minimum treatment requirements: Primary	Secondary and disinfected	Secondary coagulated filtered and disinfected	Coliform, MPN/100ml median (daily sampling)
Recreational impoundments				
No public contact		×		23
Boating & fishing only		×		2.2
Body-contact (bathing)			×	2.2

(Ohgaki, 2004)

Adapted from Asano Ch.16 Netcalf &Eddy, Wastewater Engineering

Table 1.1 Summary of Microbial and Disinfection Byproduct Rules

EPA ULTRAVIOLET DISINFECTION GUIDANCE MANUAL (June 2003 DRAFT)

Surface Water Treatment Rules - Minimum Treatment Requirements			
Regulation	***Giardia***	**Virus**	***Cryptosporidium***
SWTR	3 log removal and inactivation	4 log removal and inactivation	Not addressed
IESWTR and LT1ESWTR	No change from SWTR		2 log removal
LT2ESWTR	No change from SWTR		0-2.5 log additional treatment[1]
			2-3 log treatment[2]

Disinfection Byproduct Rules - MCLs Based on Running Annual Averages (RAAs)				
Regulation	**Trihalomethanes (TTHM) (µg/L)**	**Haloacetic Acids (HAA5) (µg/L)**	**Bromate (µg/L)**	**Chlorite (µg/L)**
Stage 1 DBPR	80 as RAA	60 as RAA	10	1000
Stage 2A DBPR[3]	120 as LRAA	100 as LRAA	No change from Stage 1	
Stage 2B DBPR[4]	80 as LRAA	60 as LRAA	No change from Stage 1	

CONTENTS

1. Water Environment Regeneration in Tokyo
2. Waterborne Pathogenic Microbial Agents
3. Wastewater Reuse

    - categories and water quality criteria -

4. Ultraviolet Disinfection Technology and Photoreactivation

(Ohgaki, 2004)

Disinfection Methods

- Heat
- Disinfactants
  (alcohol, Cl_2 , O_3 , ClO_2 , Chloramine, ・・・)
- UV
- Supersonic wave
- Electromagnetic wave
- Membrane

(Ohgaki, 2004)

Alternative Disinfection Technology

Wastewater from households

- **Sewer**
  - **Sewage treatment**
    - **Disinfection by chlorine**
      - **Residual chlorine（Chloramine）**
        - **Possible adverse effects on aquatic ecosystem**

CONVENTIONAL TECHNOLOGY

- **Altanative disinfection technology**
  - **Ultraviolet radiation**
    - **Disinfection efficiency?**
      - **Damage on DNA**
        - **Repair by photoreactivation**
          - **Photolyase**

mechanism?

RESEACH TOPICS REQUIRED

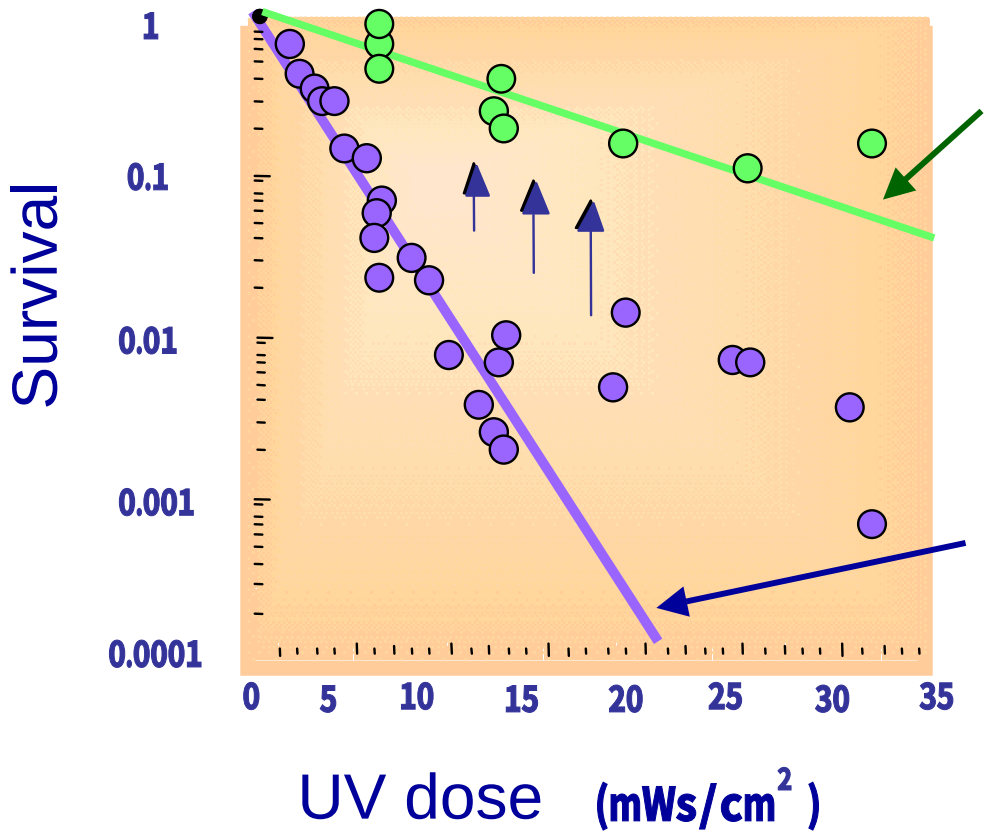
- **Mechanism of photoreactivation**
- **Quantitave estimation of photoreactivation**
- **New radiation Techniques**

Research topics required

- Photoreactivation rate **?**
- Photoreactivation degree **?**
- Difference among microorganisms **?**
- Suppress-method of photoreactivation **?**

(Ohgaki, 2004)

Photoreactivation of *E.coli*



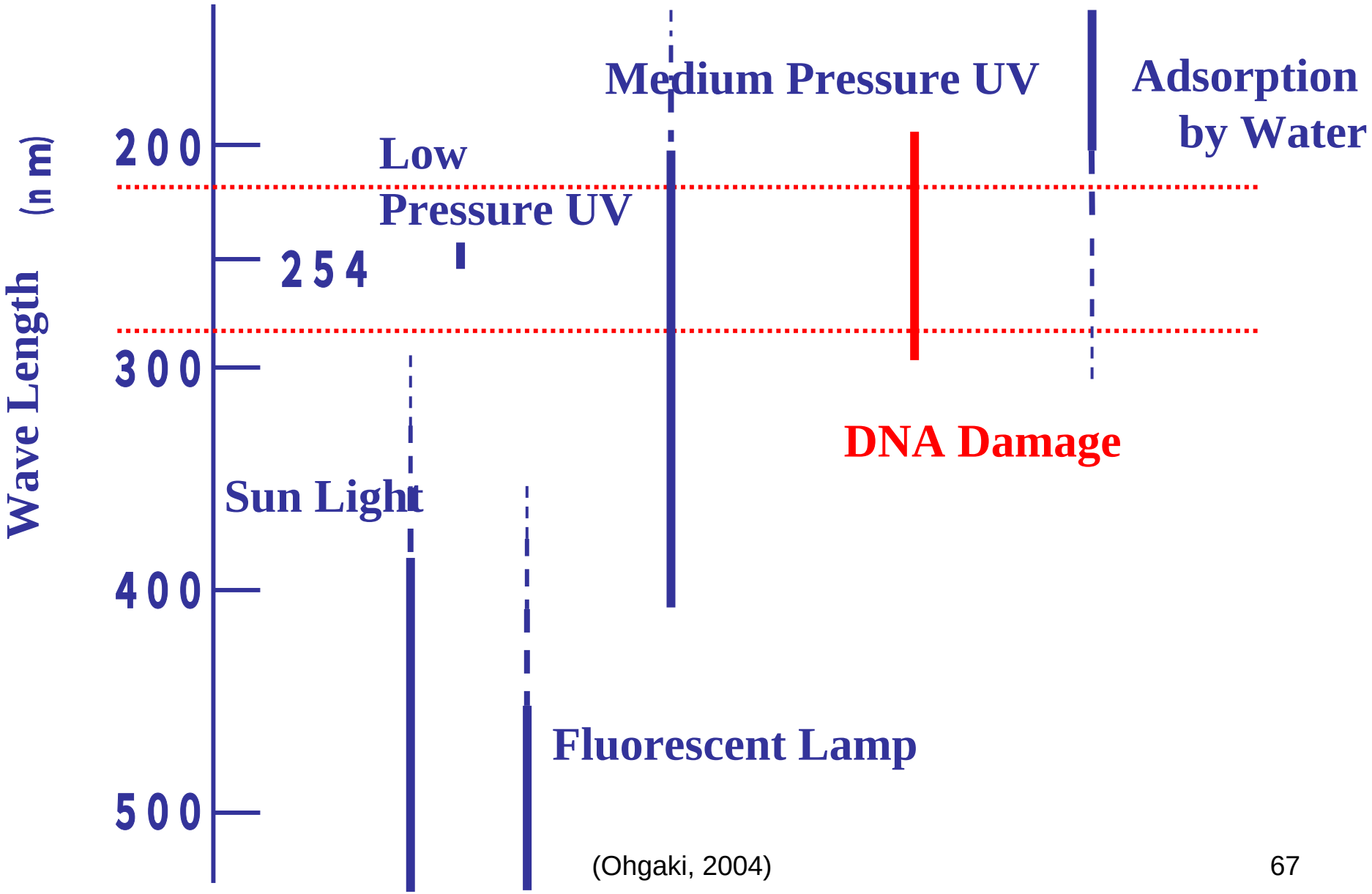
After fluorescent lamp radiation

Immediately after UV radiation

(協力：神子、大滝)

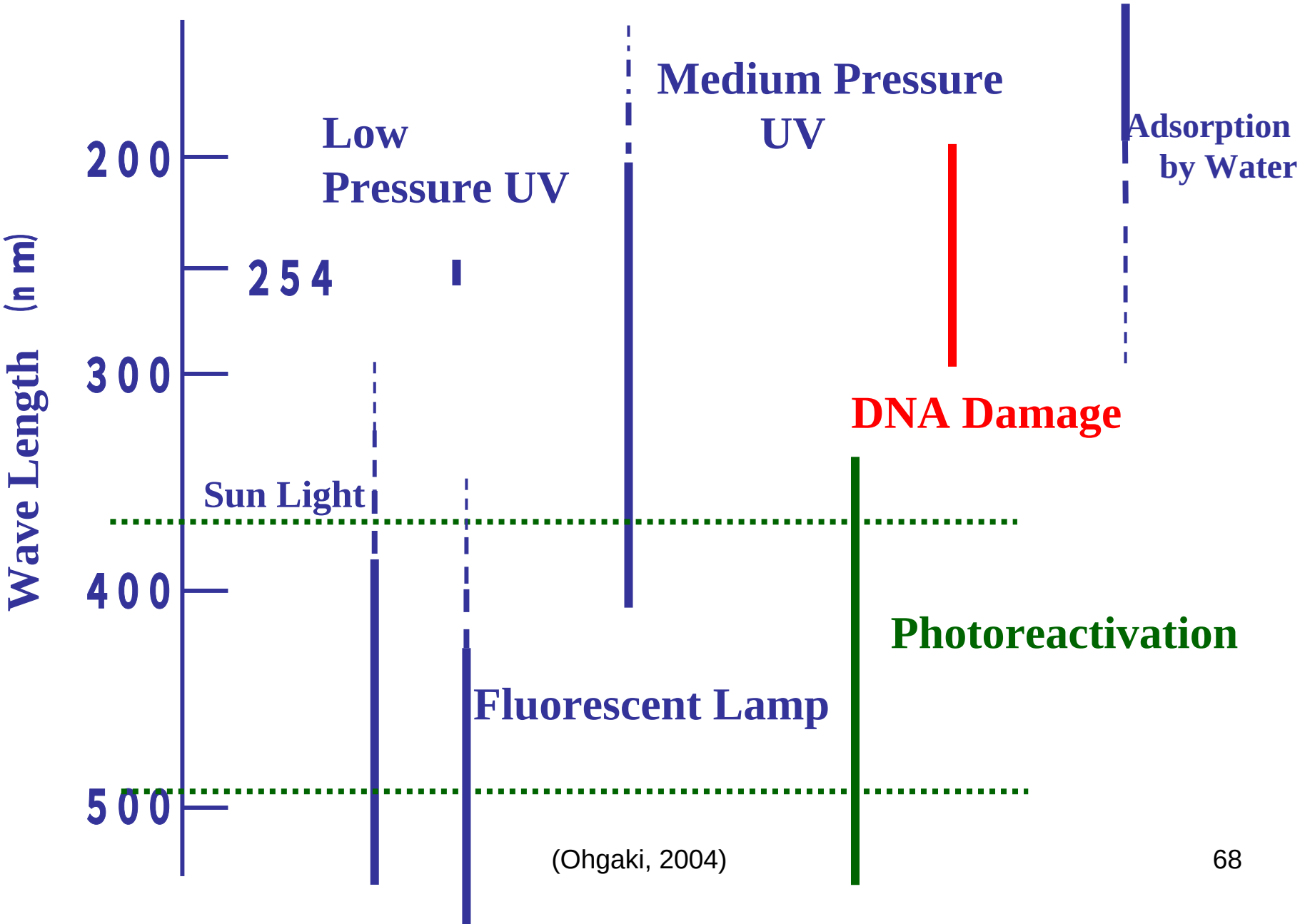
(Ohgaki, 2004)

Wave length and DNA damage



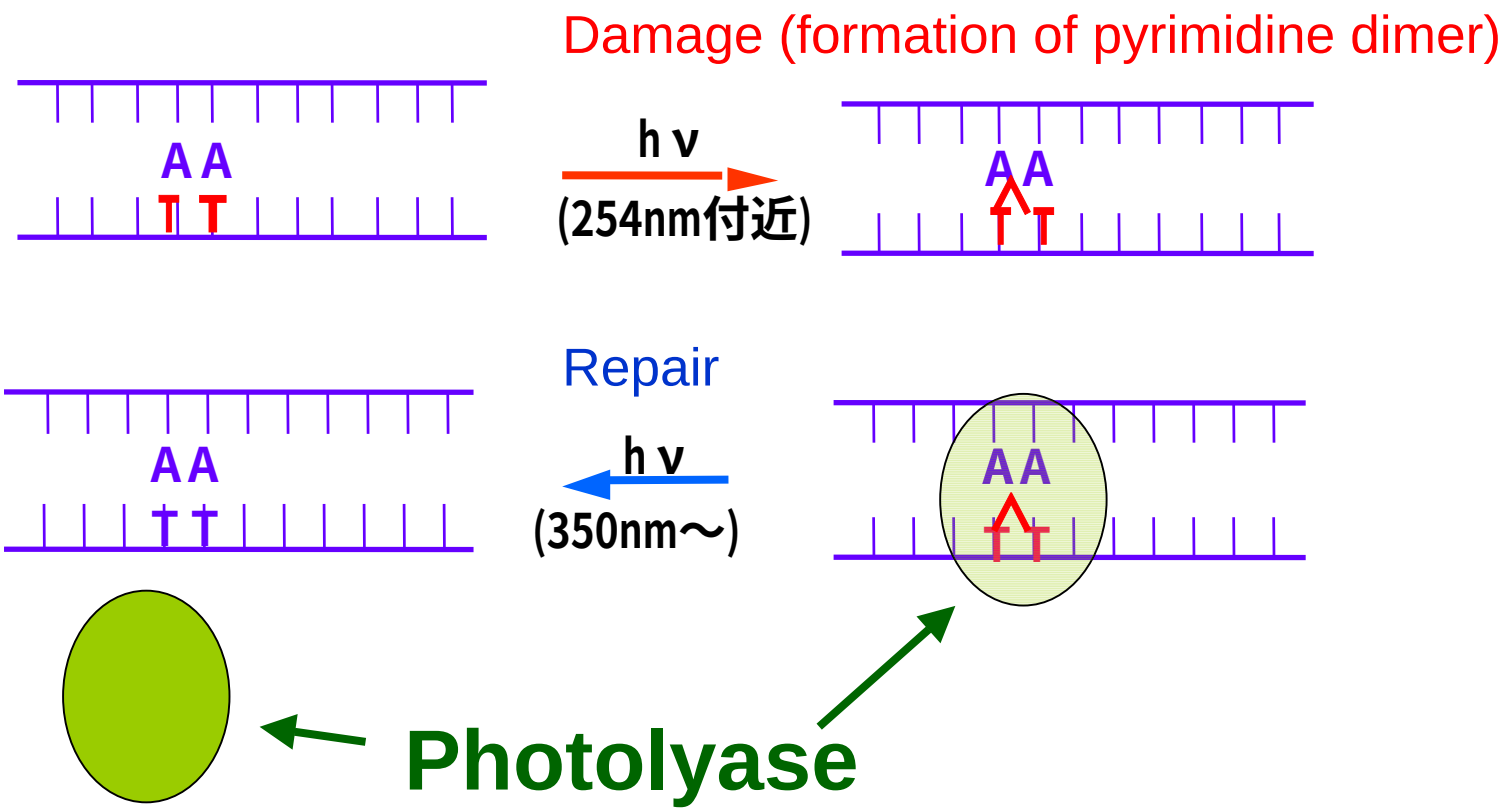
(Ohgaki, 2004)

Wave length and Photoreactivation



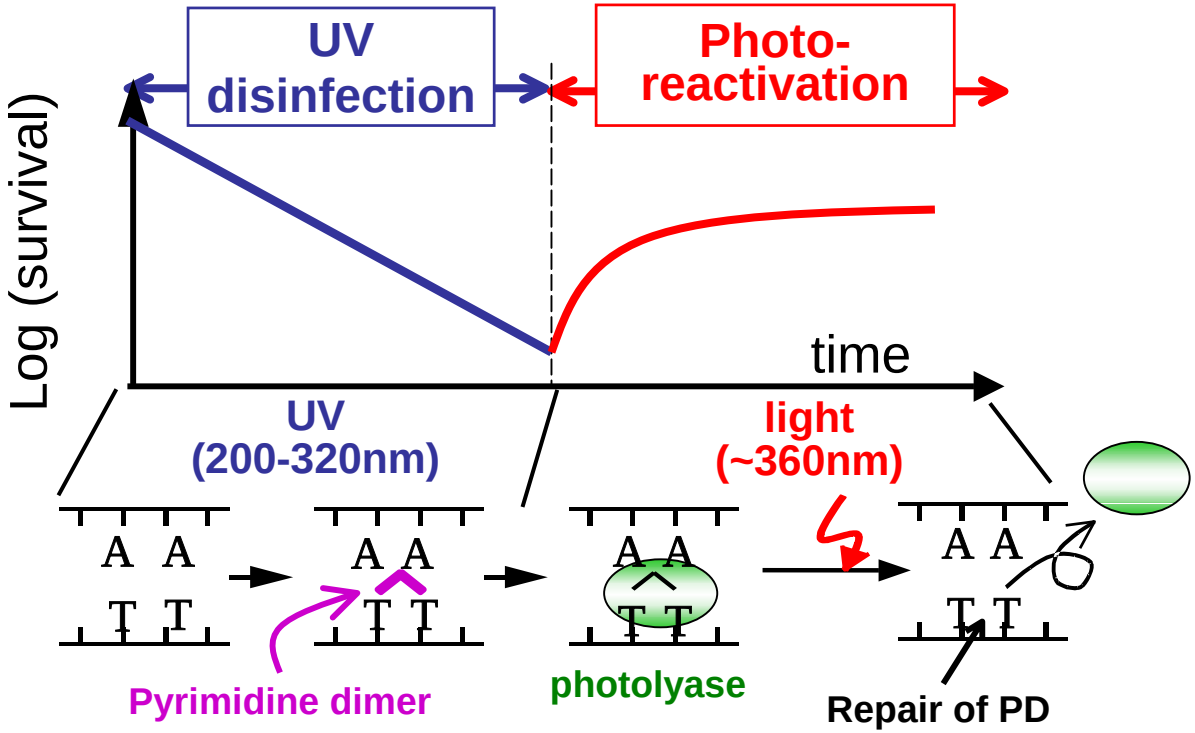
(Ohgaki, 2004)

Mechanism of Photoreativation



(Ohgaki, 2004)

UV inactivation and photoreactivation



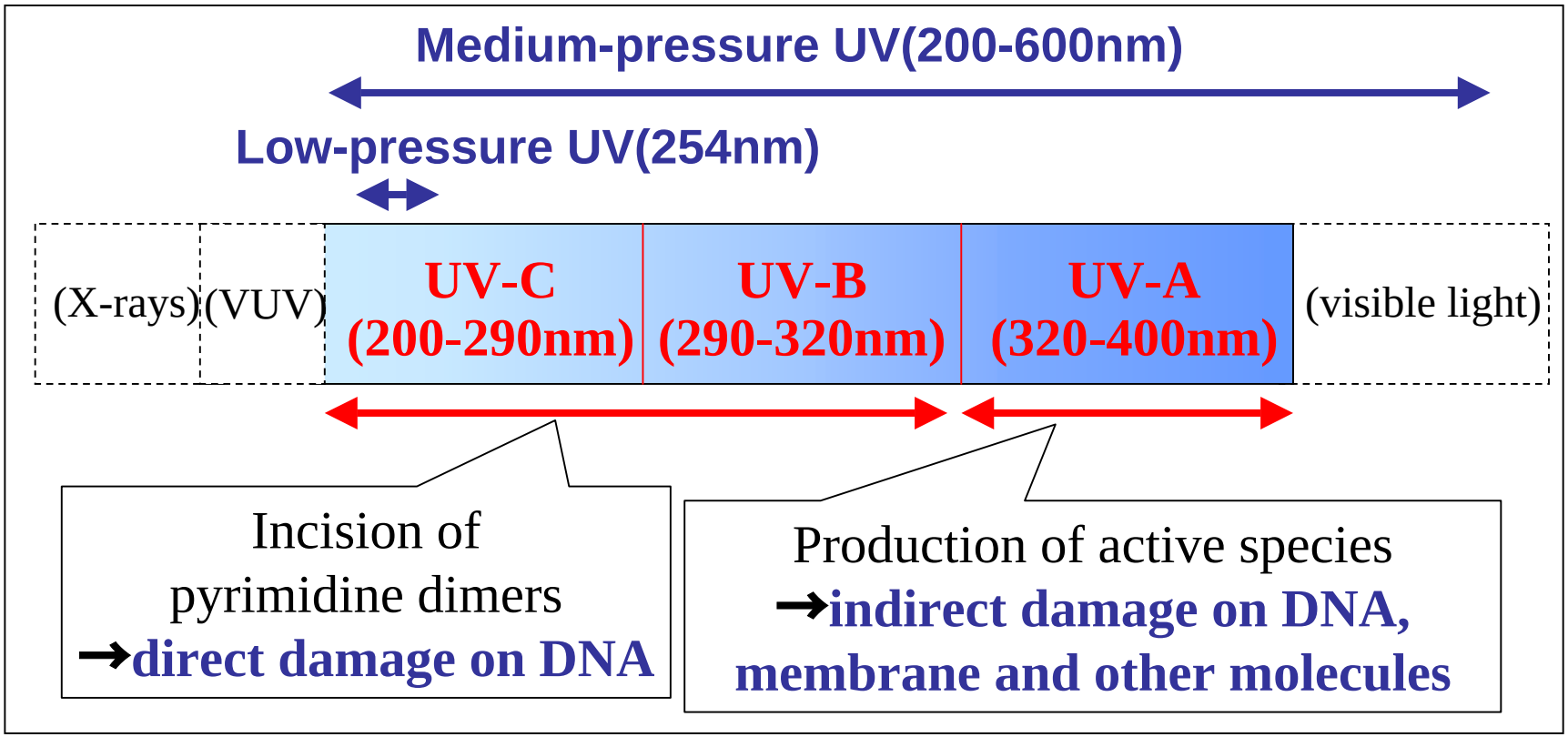
Photoreactivation is

- light-dependent
- highly specific to UV-induced pyrimidine dimers
- completed in short period (minutes to a few hours)

⇒ **a potential risk espec. in UV-treated wastewater and poolwater**

(Ohgaki, 2004)

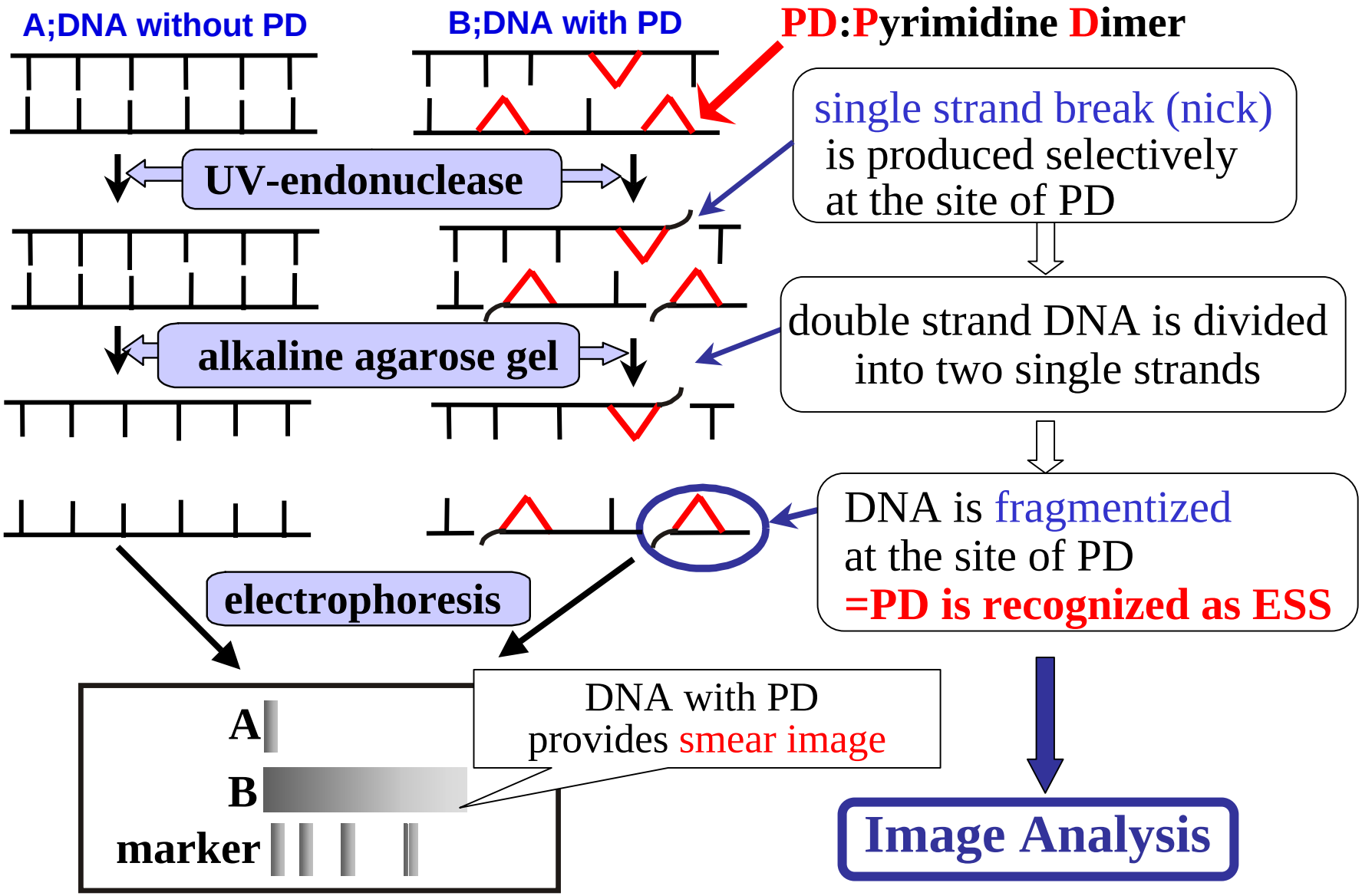
Biological effects of UV at different wavelengths



MP and LP lamps may show different characteristics in inactivation and subsequent photoreactivation because of the difference in emission wavelengths.

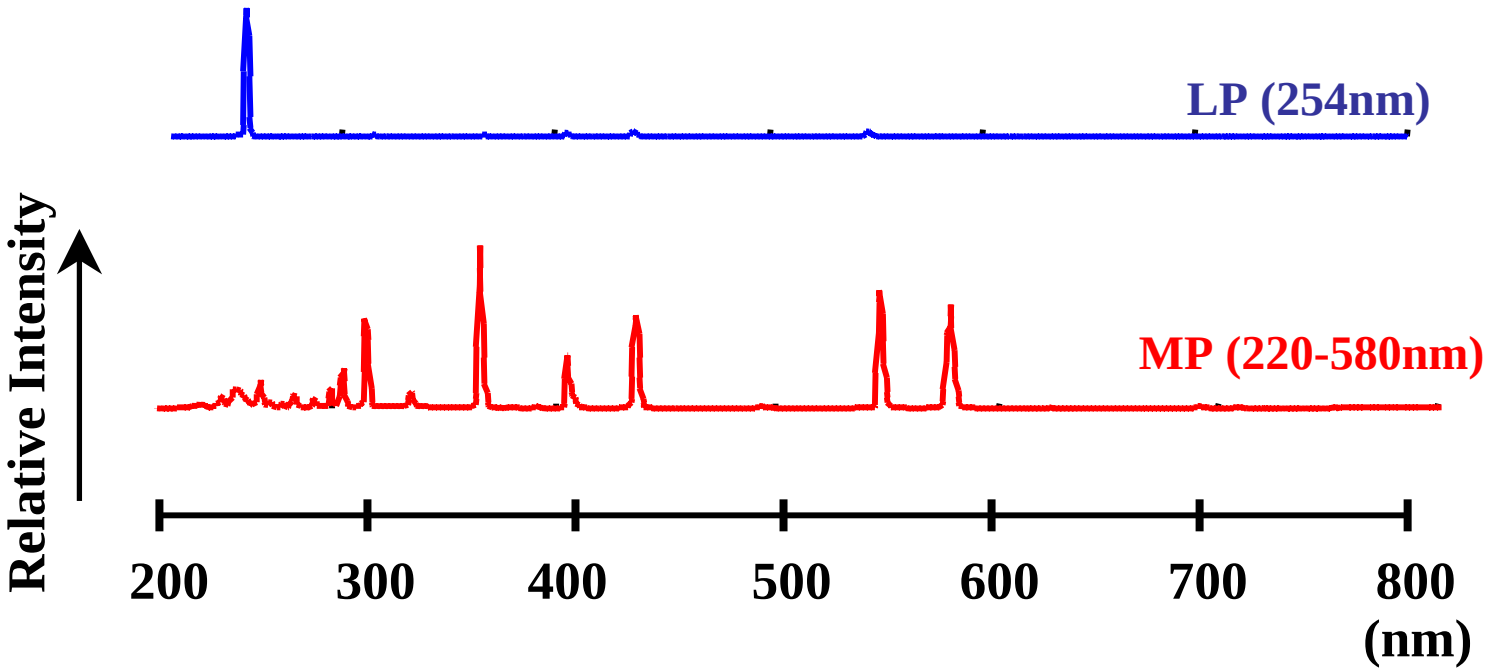
(Ohgaki, 2004)

Principle of ESS(Endonuclease Sensitive Site) assay



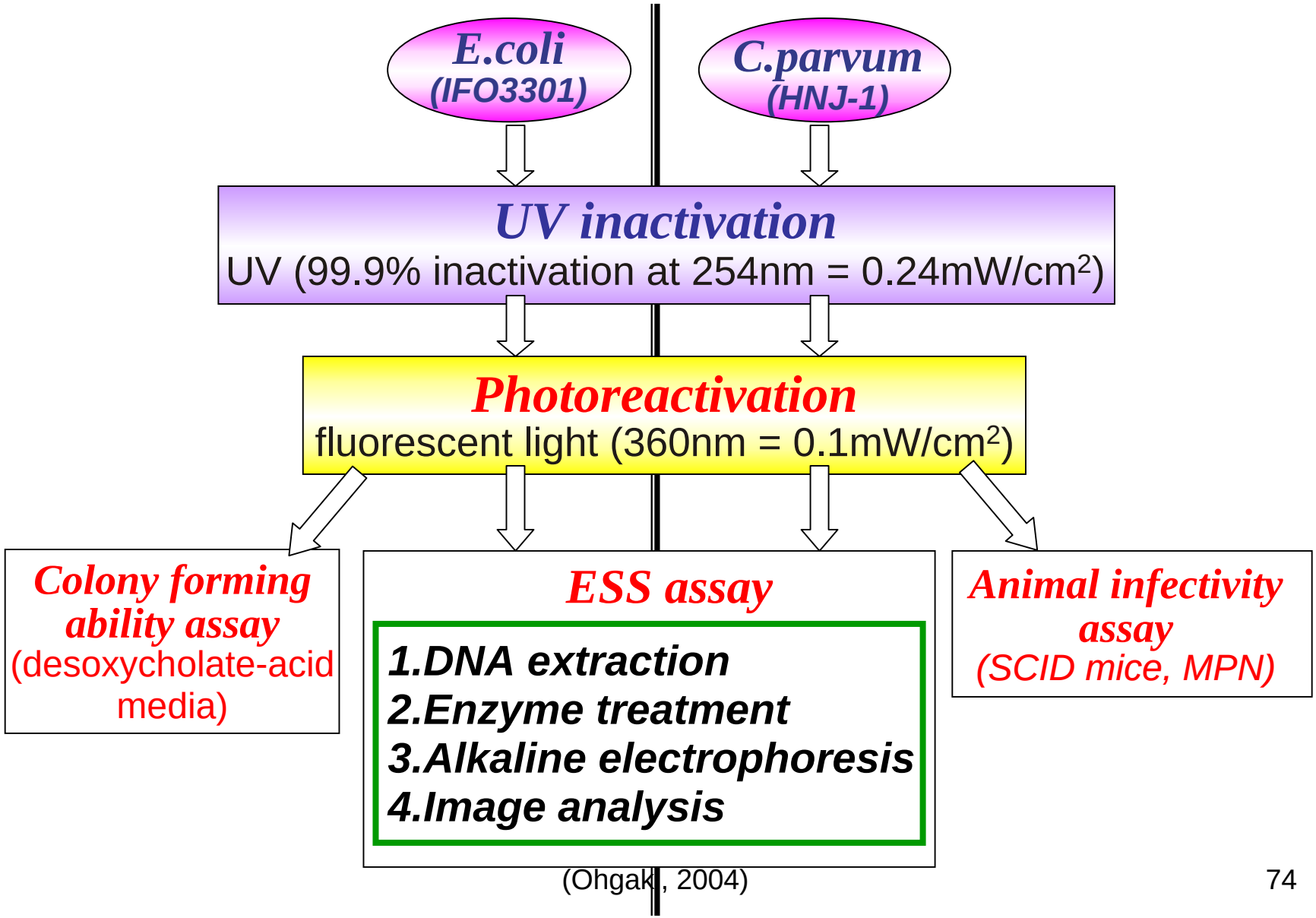
(Ohgaki, 2004)

Spectra of LP/MP lamp emissions



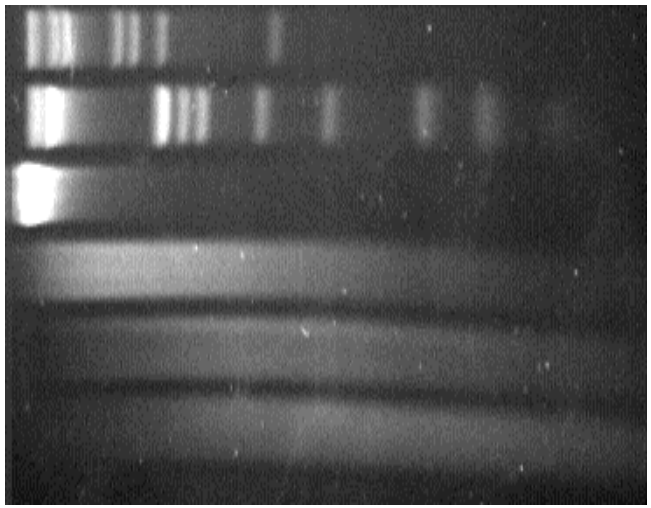
(Ohgaki, 2004)

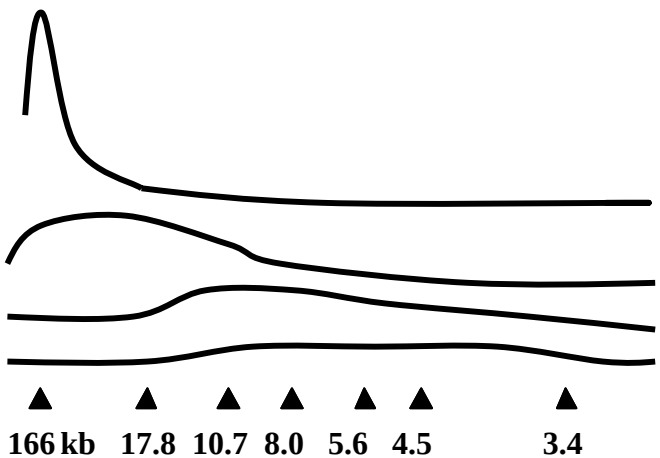
Methodology



(Ohgaki, 2004)

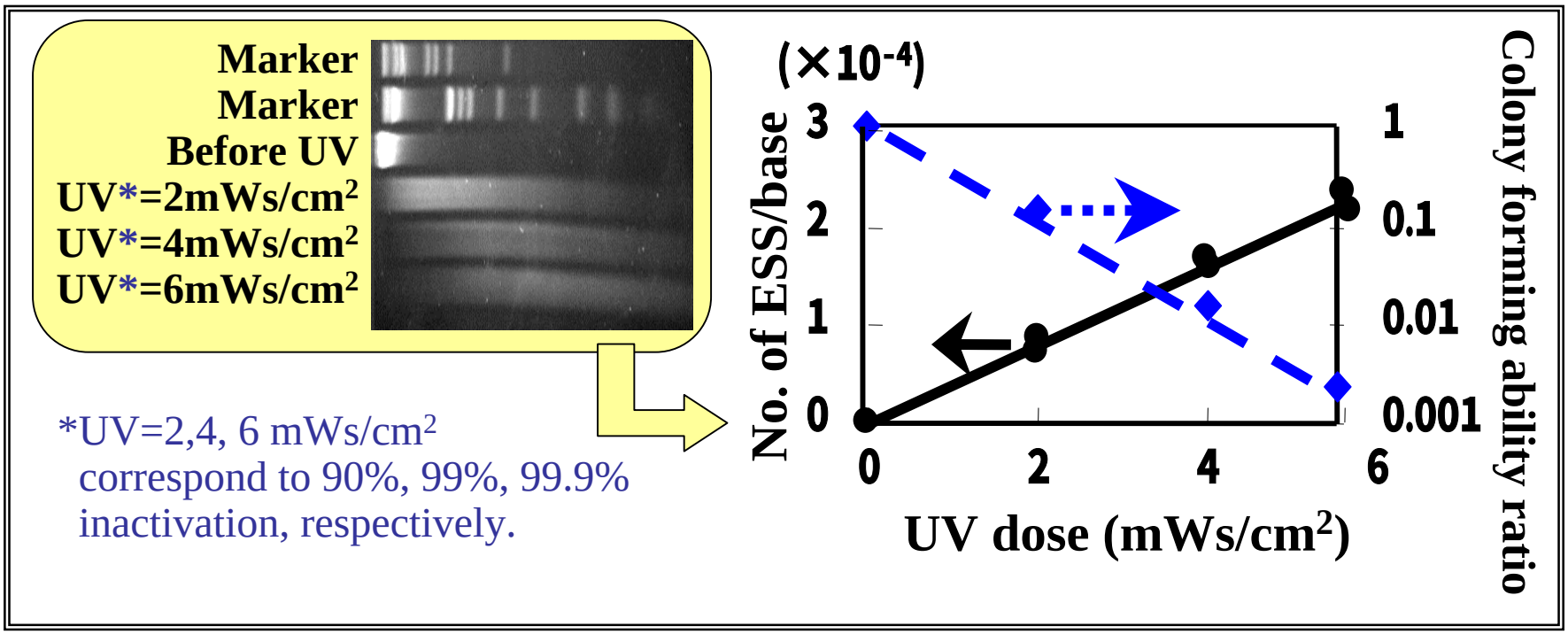
Image analysis





(Ohgaki, 2004)

Result-1; UV inactivation of E.coli

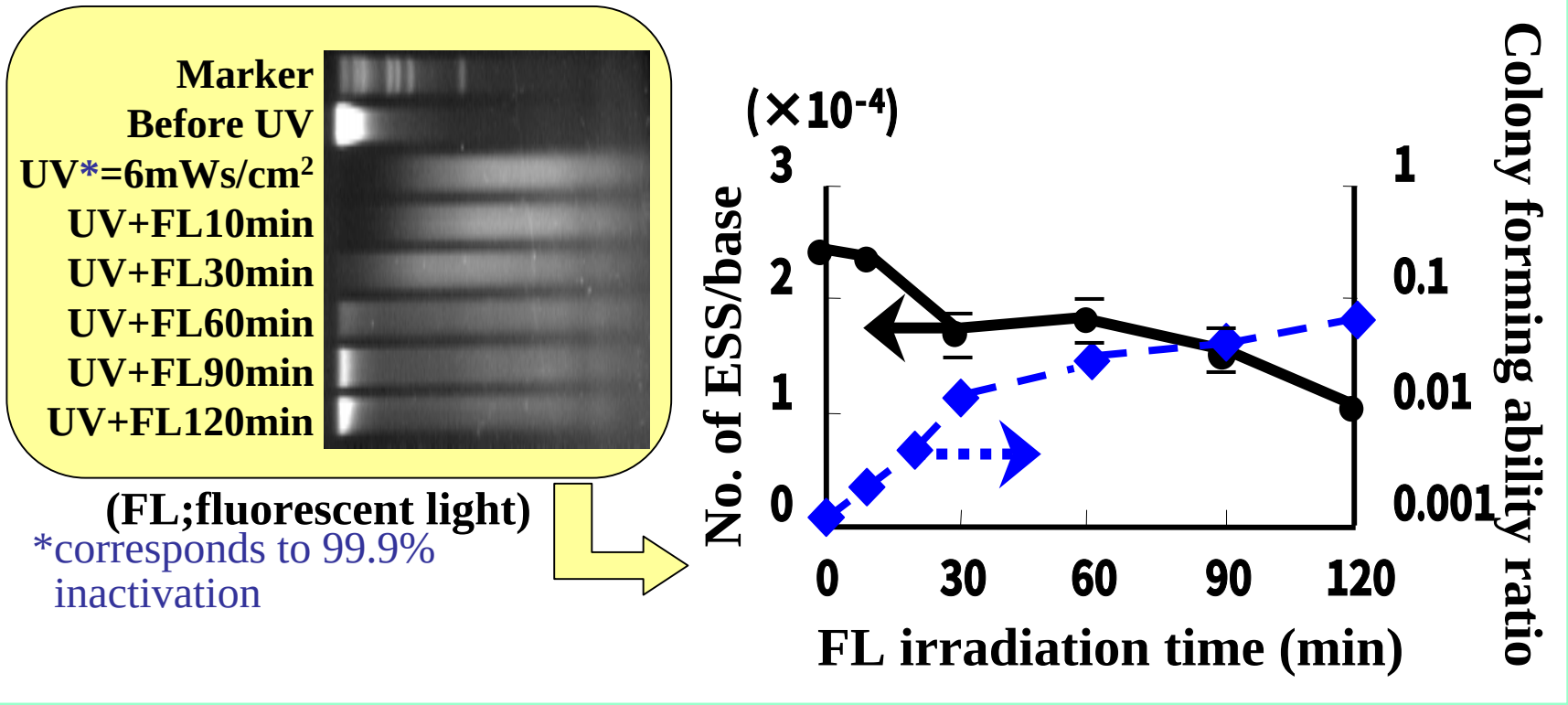


No. of ESS was highly correlated with UV dose(r^2=0.996) and also with colony forming ability(r^2=0.999)

ESS assay was applicable for the quantitative investigation of E.coli.

(Ohgaki, 2004)

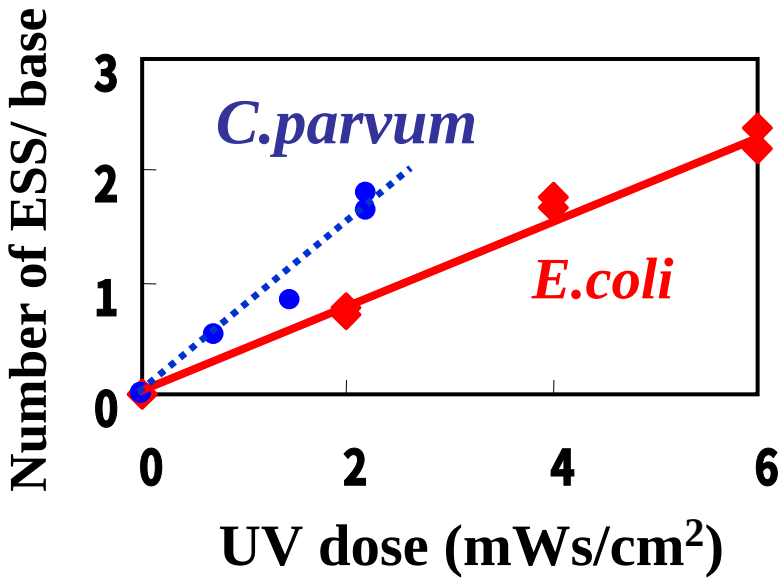
Result-2; Photoreactivation of E.coli



ESS was continuously repaired and CFA gradually recovered by FL irradiation.

(Ohgaki, 2004)

Result-5; Comparison of ESS formation

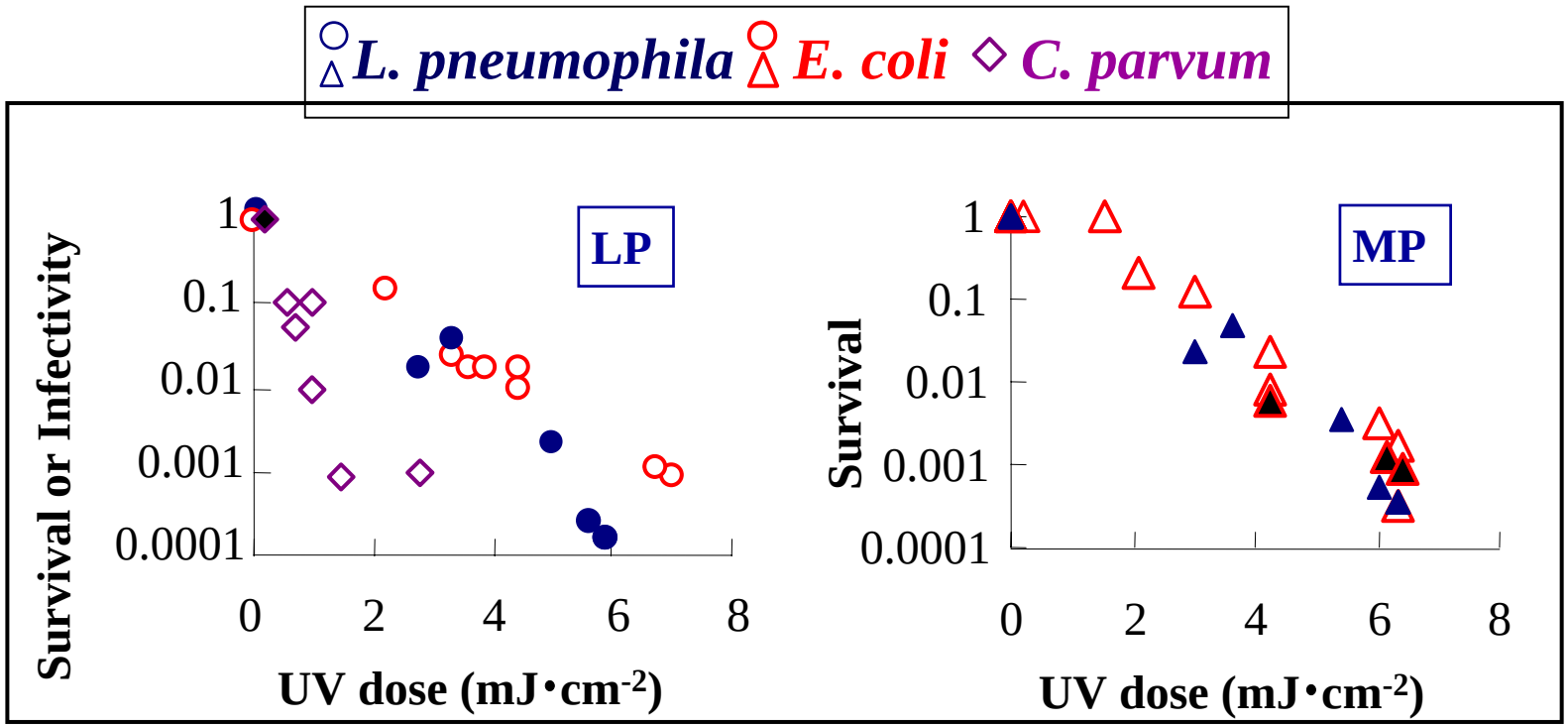


ESS formation rate for *C.parvum* was as high as that for *E.coli*.

Oocysts' cell wall would not work as a protection for UV.
⇒*might be the reason why UV can disinfect oocysts effectively compared to chemical disinfectants.*

(Ohgaki, 2004)

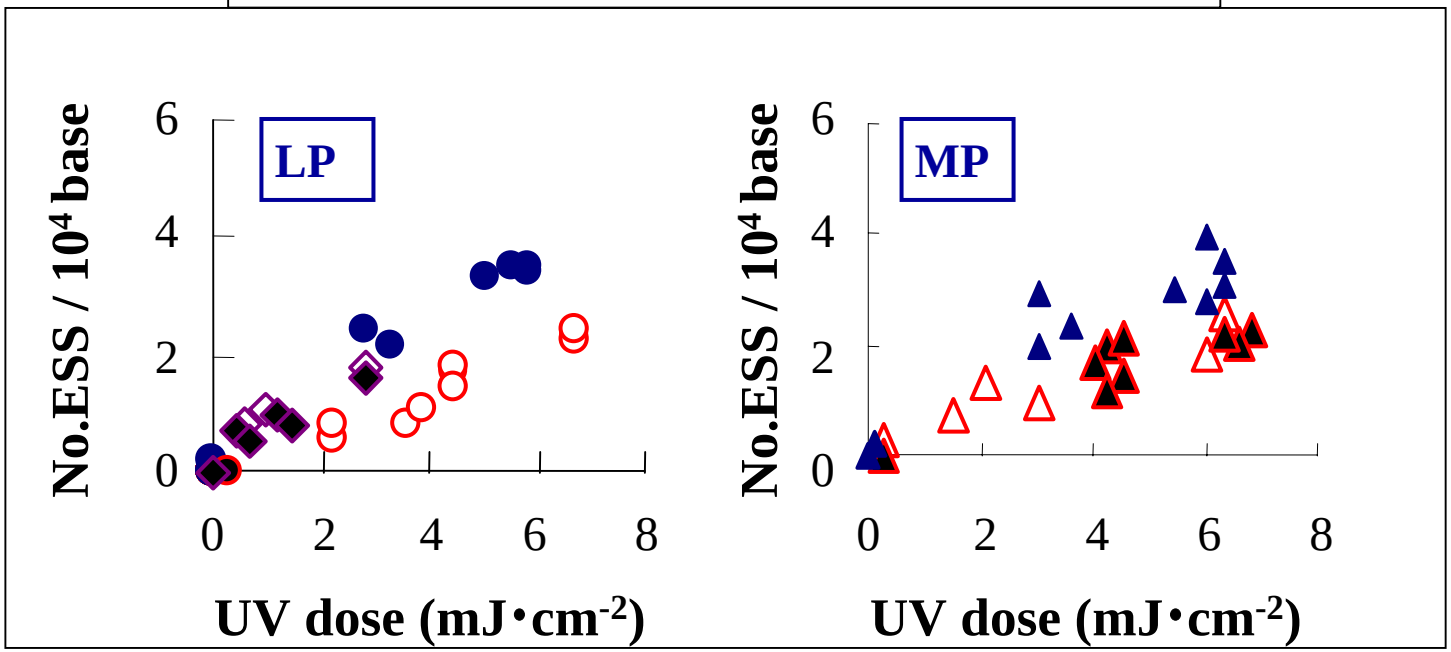
Inactivation:



➡ ･照射エネルギーあたりで評価すると、低圧/中圧ランプで不活化効率に大差はない
･クリプトは大腸菌やレジオネラよりも不活化されやすい

(Ohgaki, 2004)

Damage of genomes (number of pyrimidine dimers / endonuclease sensitive site)



ランプの別・生物種の別によらず単位エネルギー照射当たりの遺伝子損傷数に優位な差はない

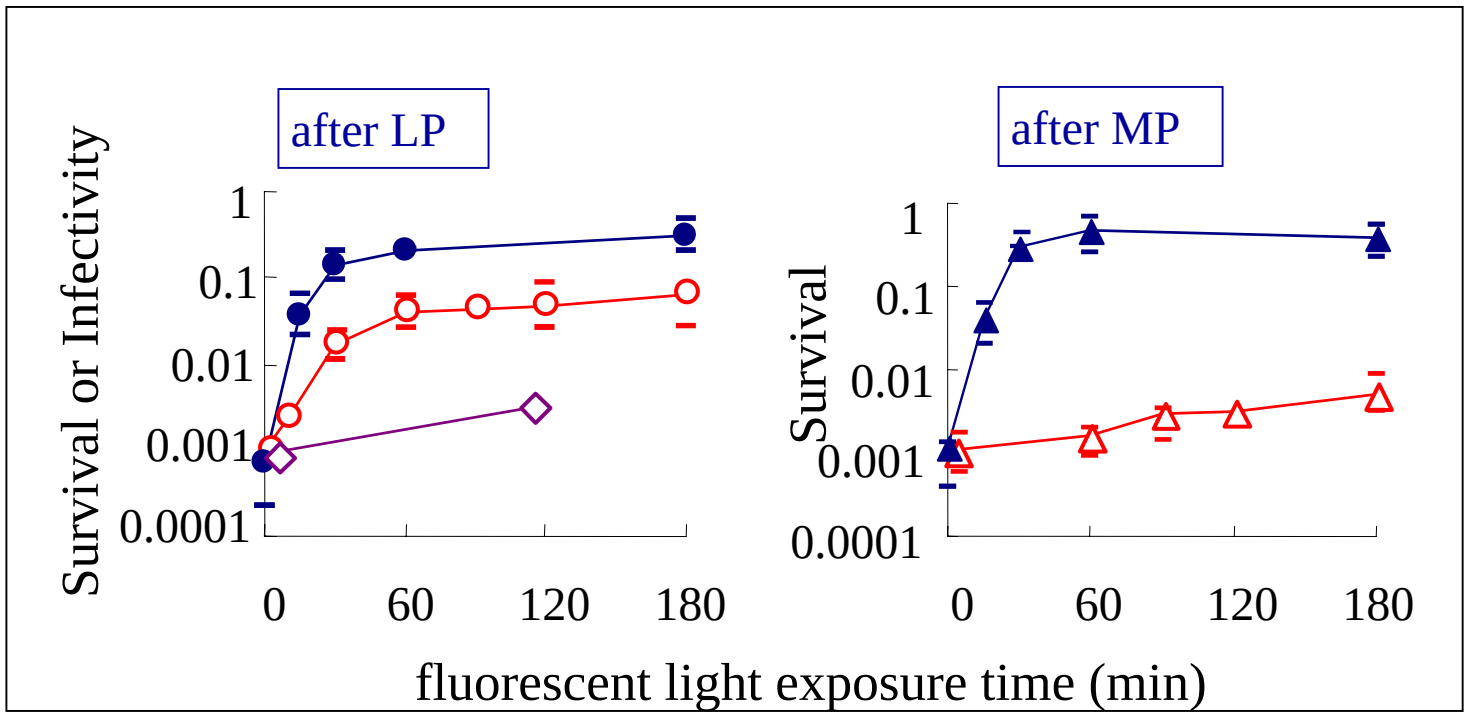
⇒クリプトのオーシスト殻はUVに対するバリアとして機能しない

⇒化学消毒剤に比べてUVが効率的にクリプトを不活化できる理由では？

(Ohgaki, 2004)

Photoreactivation (survival or infectivity)

L. pneumophila *E. coli* *C. parvum*



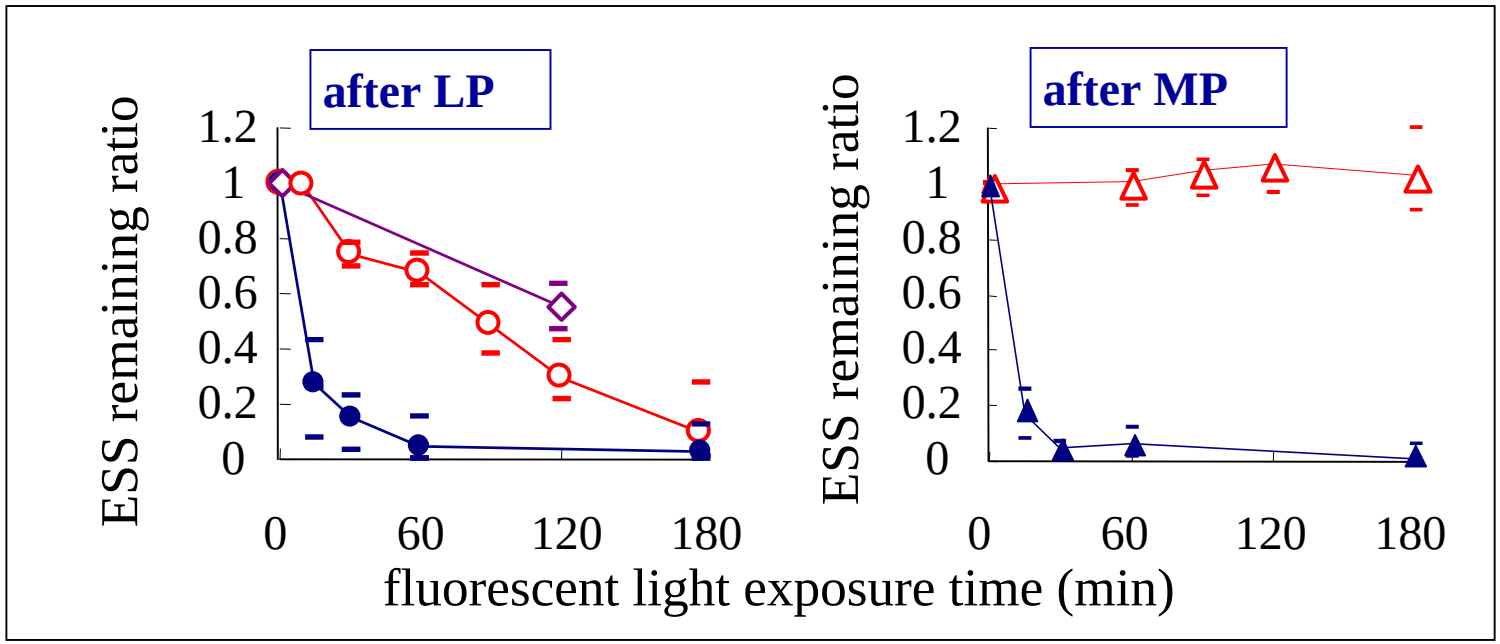
光回復によって生物活性を復活する能力:

L. Pneumophila **>>** ***E. coli*** **>** ***C. parvum***

(Ohgaki, 2004)

Photoreactivation (repair of pyrimidine dimers)

L. pneumophila *E. coli* *C. parvum*



光回復によって遺伝子損傷を修復する能力:

L. Pneumophila >> *E. coli* > *C. parvum*

(Ohgaki, 2004)

UV-Microorganisms MATRIX

Microorganism in Water	UV-Radiation
ウイルス(VIRUS)	
細菌(BACTERIA)----------	difference among species?
原生動物(PROTOZOA) -------	photoreactivation?
藻類(ALGAE) ----------	direct and indirect effect ?
線虫類(NEMATODA)----------	effect but not fatal?

(Ohgaki, 2004)

Recent Publications related to UV disinfection and pathogens

Oguma, K., H. Katayama, and S. Ohgaki. Repressive effects of yeast extract on photoreactivation of *Escherichia coli.* *Water Science and Technology* 50 (1), 2004 (in press).

Oguma, K., H. Katayama, and S. Ohgaki. Photoreactivation of Legionella pneumophila after inactivation by low- or medium-pressure ultraviolet lamp. *Water Research* 38. 2757-2763. 2004.

Otaki,M., A.Okuda, K.Tajima, T.Iwasaki, S.Kinoshita and S.Ohgaki, Inactivation differences of Microorganisms by Low Pressure UV and Pulsed Xenon Lamps, *Water Science and Technology*, Vol.47, No.3, pp185-190, 2003

Ohgaki,S., M.Z.B.Alam, K.Oguma, UV-disinfection and Photoreactivation: Complex Effects of Light on Microorganisms, *Water Resources and Water Supply in the 21st Century*, Hokkaido University Press, pp167-176,2003

Oguma, K., H.Katayama, S.Ohgaki, Photoreactivation of Escherichia coli after Low- or Medium-Pressure UV Disinfection Determined by an Endonuclease Sensitive Site Assay, *Applied and Environmental Microbiology,* Vol.68, pp.3029-6035, 2002

Masago,Y,H. Katayama, A. Hashimoto, T. Hirata and S. Ohgaki, Assessment of risk of infection due to Cryptosporidium parvum in drinking water, *Water Science & Technology,* Vol.46, No.11-12, pp. 319-324, 2002

Morita, S., A.Namikoshi, T.Hirata, K.guma, H.Katayama, S.Ohgaki, N.Motoyama, and M.Fujiwara, Efficacy of UV Irradiation in Inactivating Cryptosporidium parvum Oocysts, *Applied and Environmental Microbiology*, Vol.68, No.11,pp.5387-5393, 2002