Water Management

Strategies	Long-term Goals	2018 Achievements	2019 Targets
Risk Management of Water Resources Enforce climate change mitigation policies, implement water conservation and water shortage adaptation measures	• Reduce unit water consumption (liter / 8-inch wafer equivalent number of reticles) to 30% (2010 as the base year) Target Year: 2020	Unachieved • Reduced water consumption (liter / 8-inch e wafer-layer) by 24.7% (2010 as the base year) with an achievement rate of 95%[Note1] Target: 26%	• Reduce water consumption (liter / 8-inch e wafer-layer) by 26% (2010 as the base year)
Develop Diverse Water Sources Integrate internal and external company resources to develop regenerated water technology; implement water conservation and the use of regenerated water in the manufacturing process	• Save up to 12.77 million tons of water between 2016 to 2025 by adopting new water conservation measures Target Year: 2025 • Use regenerated water to replace 50,000 tons of tap water per day Target Year: 2025	Unachieved • Saved 1.274 million tons of water after adopting new water conservation measures with an achievement rate of 99.5%[Note2] Target: 1.8 million tons	• Save an additional 1.14 million tons of water through newly-adopted water conservation measures
Develop Preventive Measures Improve the efficiency of water pollution prevention and removal of water pollutants	• Meet effluent water quality standards for wastewater discharge NEW Target Year: 2025 • Increase the usage rate of regenerated water by more than 20% Target Year: 2030	Surpassed • The average concentration of NH_4-N in company wastewater discharge was 21 ppm Target: <30ppm	• Tetramethylammonium hydroxide (TMAH) < 8 ppm • Copper ion (Cu^{2+}) < 0.15 ppm

Surpassed | Achieved | Unachieved

Note 1 There was an increase in water usage from newly-built fabs, but production has not yet started.

Note 2 A portion of water saving projects were completed in January 2019, and as a result were not included in total water saved in 2018.

Expand Sources and Reduce Consumption to Ensure Sustainable Production

Water is a precious life-giving resource for our planet. In recent years, the impact of global climate change is tipping the balance between water supply and demand. As a global citizen, TSMC is taking concrete action to expand new resources and cut down on consumption by actively integrating internal and external resources. It has invested great effort in water resource risk management, expansion of diverse water sources, and the development of pollution prevention techniques while cooperating with external partners to ensure sustainable production.

Risk Management of Water Resources

Establishing an Effective Index for Monitoring Water Use

With a comprehensive water reporting system, TSMC monitors the volume of each reservoir and the water usage rate at every plant, thereby establishing an effective water resource management index. During a water shortage in Tainan County from January to May 2018, TSMC took action prior to the government's announcement of Stage One water restrictions, such as reducing landscaping irrigation by 50% and decreasing pressure in its water supply. It also saved up to 3% of water, lowering demand from reservoirs and mitigating the impact of the water shortage on the environment.

Pre-emptive Water Management Measures

TSMC Water Resource Management Benchmarks	Government Water Status Indicator	Government Water Restriction Measures	Situation in 2018
Establish a comprehensive water use monitoring system → Early warning of long-term water use trends → Assess water installations for any improvements	Blue Normal	Stabilize supply and demand	• Constantly monitored the water supply of every reservoir as reported by the Water Resources Agency, and held periodic drills
Create a contingency group → Assess the demand for water tankers / reserve water sources → Formulate and negotiate water conservation guidelines between fabs	Green Slight Water Shortage	Encourage farmers to leave lands fallow	• Created a contingency group to take inventory of water sources and water tanker capacity • Lowered water supply pressure by voluntarily reducing water use by 3%
Voluntarily reduce water consumption by 3% → Formulate a systematic water conservation mode → Practice drills in using water tankers to transport water	Yellow Stage One	Decrease water supply pressure during specific time intervals	• Did not occur
Implement water restrictions at all levels and enforce necessary water conservation measures → Cross-organizational drought emergency response team → Systematic water conservation and water transportation via water tankers	Orange Stage Two	Industrial Consumers 5-20% cut in water supply	• Did not occur
	Red Stage Three	Rotating Water Outages	• Did not occur

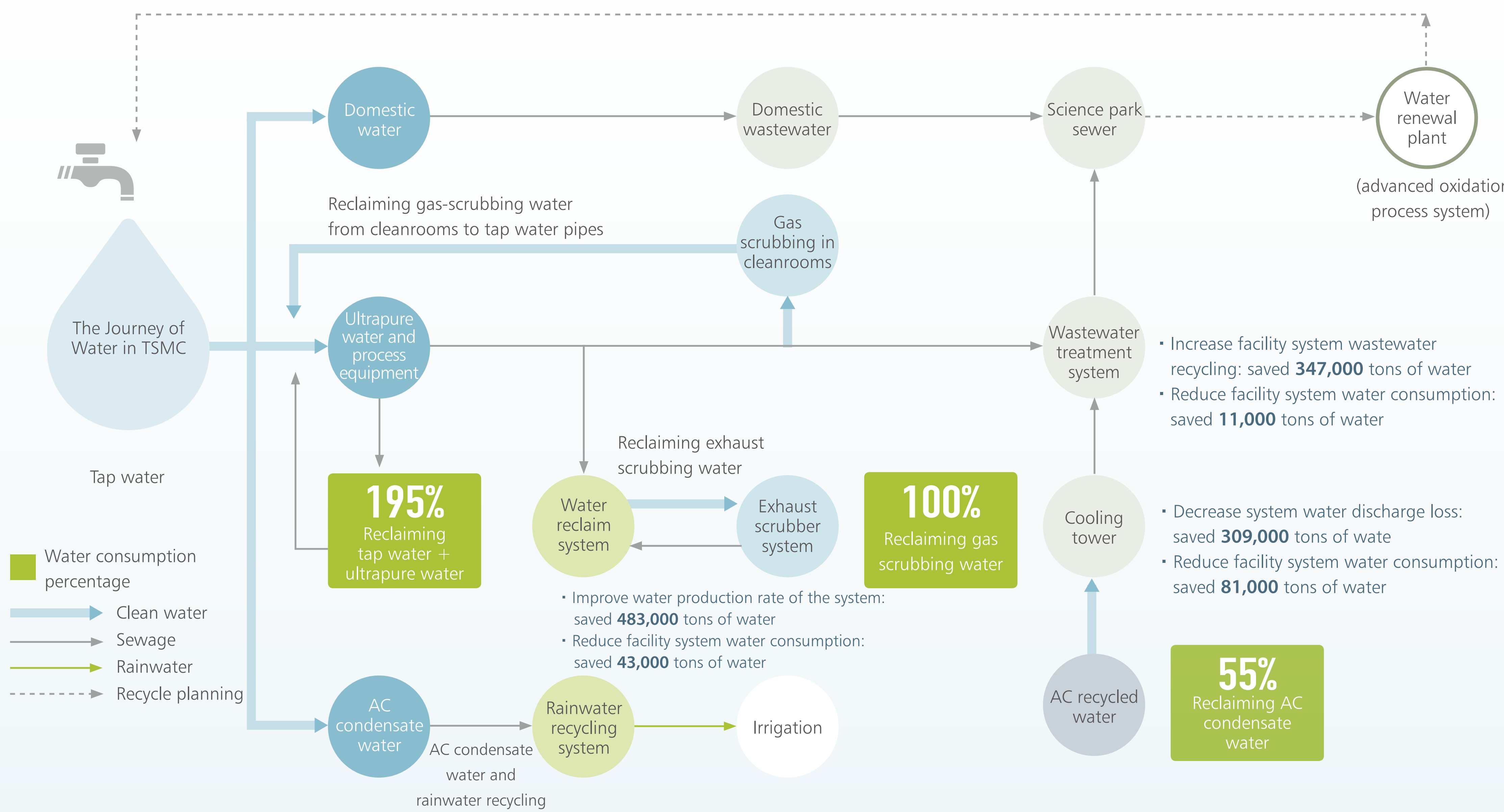
Actively Promote Water Recycling

In order to use water more efficiently, TSMC categorizes wastewater from purification and processing equipment according to purity. The cleanest water is given priority to be purified and recycled for use in the manufacturing process; the next grade goes through water recycling system treatment to serve as water for non-manufacturing processes; unrecyclable wastewater is discharged to an on-site wastewater treatment plant for terminal wastewater management. TSMC has invested considerable effort into building various wastewater recycling systems to enable water purification and reuse. Through layers of recycling, all tap water is completely reclaimed every day. Each drop of water can be used an average of 3.5 times. In 2018, the total amount of water recycled by TSMC reached a record high of 129 million tons, equal to 4.1 times the volume of the Second Baoshan Reservoir.

How one drop of water can be used 3.5 times?

$$\frac{\text{Tap water} + \text{Recycled water}}{\text{Tap water}} = \text{Water usage times}$$

Main Water Cell and On-site Recycling System



Note Water consumption percentage is the ratio of recycled water to tap water, or in other words, the proportion of water recycling volume to water consumption volume in treatment. Proportions of these water treatment equipment may vary depending on allocation by the science parks

New Water Conservation Measures in 2018

Water recycling has become a more urgent issue than ever as advanced process technologies take a larger proportion of the Company's production, IC line widths continue to shrink, requirements for product purity continue to rise, and water needed per unit wafer of production continues to increase. In an effort to develop more water-saving methods, TSMC's water conservation guidelines focus on four aspects: reduce water consumption by facility systems, increase wastewater recycling in facility systems, improve system water production rates, and decrease water discharge loss from the system.

In 2018, the Company enhanced the effectiveness and expanded the scale of the ten existing water-saving measures. It also took a further step by putting sludge supernatant into coagulation-precipitation treatment through strict separation for water reuse. This method not only puts water conservation into practice, but it reduces wastewater and sludge. In 2018, an additional 1.27 million tons of water was conserved.

Many newly-built TSMC fabs (Fab 15B) began operating in 2018. To deal with the increasing consumption of tap water, TSMC has continued to propose many innovative water conservation measures to improve the water use efficiency, water recycling rate, and recycling volume of advanced manufacturing processes. In total, water use intensity (Water Consumption Per Wafer-layer) in 2018 decreased 24.7% from 62.6 (liter / 8-inch e wafer-layer) in 2010 to 47.1 (liter / 8-inch e wafer-layer). The rate of reduction was down from 2017 due to water consumption by newly-built facilities.

Water Conservation Measures and Results in 2018

Annual Additional Water Conservation Amount 1,274,000 tons

Decrease water discharge loss from the system
- Recycle discharged water from cooling towers 81,000 tons (6.4%)

Improve water production rate of the system
- Increase the water production rate of RO recycling systems 241,000 tons (18.9%)
- Improve usage efficiency by allocating recycled water 240,000 tons (18.9%)

Increase wastewater recycling of facilities
- Recycle hydrofluoric acid wastewater 229,000 tons (17.9%)
- Recycle water from TMAH treatment 86,000 tons (6.7%)
- Purify recycled water into industrial water 11,000 tons (0.9%)

NEW Recycle supernatant sludge 22,000 tons (1.7%)

Reduce water consumption of facilities
- Reduce cooling tower and sand filter backwash water 310,000 tons (24.3%)
- Extend the duration of regeneration and backwash cycles in pure water and recycling systems 44,000 tons (3.4%)
- Conserve kitchen cleaning water in office buildings 11,000 tons (0.9%)

Water Conservation Effectiveness

	2014	2015	2016	2017	2018
Average recycling rate of water for manufacturing processes (%)[Note1]	87.6	87.3	87.4	87.5	87.5
Ultrapure water consumption (Million metric tons)[Note2]	56.6	61.0	68.8	79.7	85.1
Tap water consumption (Million metric tons)[Note2]	38.2	37.5	42.0	49.0	56.8
Total amount of water recycling (Million metric tons)[Note3]	81.0	85.6	94.3	103.4	129.0
Equivalent volume of the Second Baochan Reservoir (number)[Note4]	2.57	2.72	3.00	3.29	4.10
Equivalent volume of a standard swimming pool (number)[Note5]	32,396	34,252	37,732	41,360	51,612
Number of times each drop of water is used	3.3	3.5	3.5	3.5	3.5

Note 1 Statistics are calculated by a standard formula assigned by the Science Park Administration

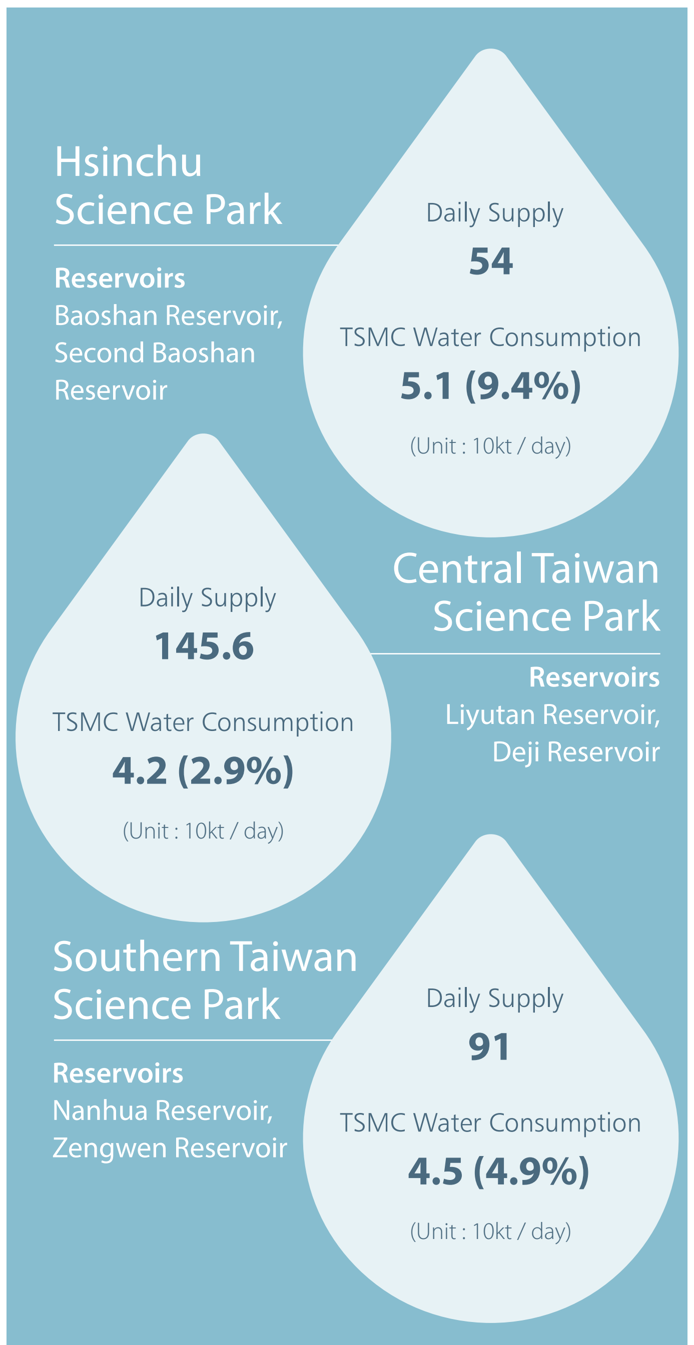
Note 2 Ultrapure water and tap water consumption includes numbers from Taiwan sites (all wafer fabs and back-end assembly facilities), WaferTech, TSMC (China), TSMC (Nanjing) and VisEra

Note 3 Total amount of water recycling includes all data from Taiwan sites (all wafer fabs and back-end assembly facilities in Taiwan)

Note 4 The water in Hsinchu Science Park is mainly supplied by the Second Baoshan Reservoir, whose full capacity amounts to 31.49 million tons

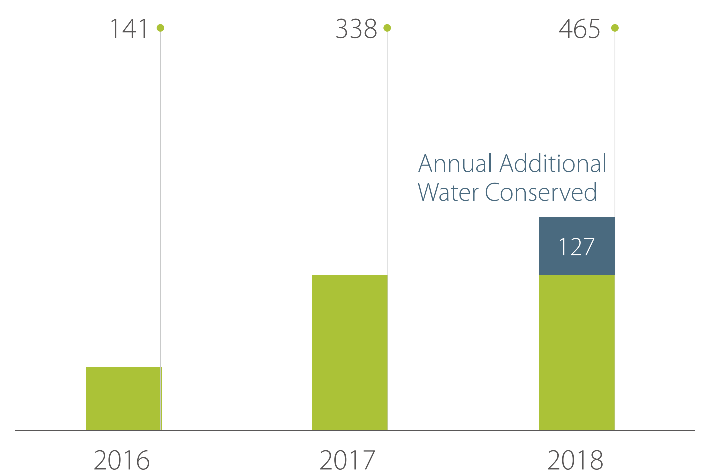
Note 5 A standard swimming pool is 50x25x2 meters in size, or 2,500 tons in volume

TSMC Water Consumption Rate at Three Science Parks



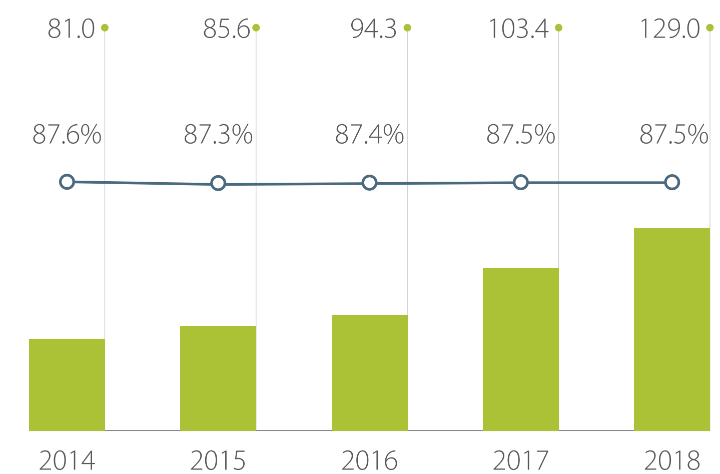
Annual Water Conserved

Unit: Ten thousand tons



Note Reservoir capacity is according to the water supply information of all regions published on the Water Resources Agency website. The capacity of reservoirs supplying Central Taiwan Science Park includes numbers from Taichung and Miaoli

Water Recycling and Usage Efficiency

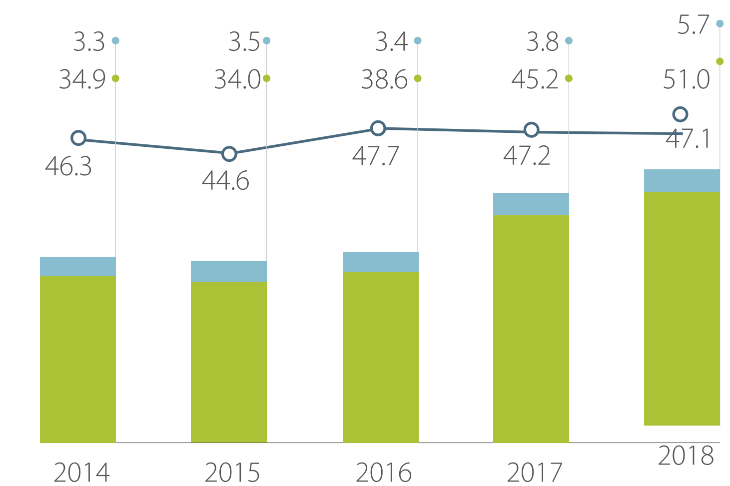


Total amount of water recycled (Million metric tons)
Average Process Water Recycling Rate (%)

Note 1 Total amount of water recycled includes numbers from manufacturing process water treatment and recycling as well as manufacturing process water recycling in scrubber towers

Note 2 The total amount of water recycled is 2.5 times the volume of tap water consumption

City Water Consumption and Water Consumption per Wafer-Layer



Total tap water consumption of subsidiaries (Million metric tons)
Total tap water consumption in Taiwan facilities (Million metric tons)
Water Consumption Per Wafer-layer (liter / 8-inch e wafer-layer)

Note 1 Tap water consumption includes numbers from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra

Note 2 The indicator for water usage per wafer-layer represents data from all wafer fabs of TSMC and subsidiaries

Develop Diverse Water Sources

TSMC's water sources include tap water, air conditioning (AC) condensate water, and rainwater. Tap water is used for manufacturing processes and domestic purposes; AC condensate, for manufacturing processes and irrigation; and rainwater, for irrigation systems. In order to cope with water shortages and comply with water supply diversity policies, TSMC has been developing water reclamation technologies since 2015. Currently, the Company has successfully decreased the number of water quality factors, such as total organic carbon (TOC), carbamide, and electric conductivity in wastewater, and it now meets water management standards for manufacturing processes in wafer fabs. The quality of its wastewater has also reached effluent discharge standards. TSMC's achievements all mark a significant development milestone in water reclamation. In addition, the Company succeeded in reducing the unit cost of water production by 40% and made regenerated water more economical in 2017. TSMC also began to find partner firms for the establishment of a water reclamation plant for its Southern Taiwan Science Park (STSP) site, and the plant is expected to be approved and constructed in 2019, providing 20,000 tons of industrial regenerated water per day. In the future, TSMC will continue to promote the development of water reclamation and support it with tangible actions to expand the supply and recycling of sustainable fresh water.

Timeline of Highlights for Regenerated Water

- **2015**
  - Began the development of water reclamation techniques
- **2016**
  - Fab 14 (P5) establishes "Wastewater Effluent Recycling Pilot Plant
  - Reached production line standards for regenerated water quality
- **2017**
  - 40% reduction in the unit cost of water production
- **2018**
  - Find partner firms for the establishment of a water reclamation plant in STSP
- **2019**
  - Establish a water reclamation plant in STSP
  - Establish a water reclamation plant in Yongkang, Tainan
- **2021**
  - Supply 20,000 tons of water from the water reclamation plant in STSP
  - Supply 9,500 tons of water from the water reclamation plant in Yongkang, Tainan
- **2022**
  - Supply 37,500 tons of water from the water reclamation plant in Anping, Tainan

Note The actual schedule of introducing regenerated water may be adjusted according to the water supply timetable in water reclamation plants

Develop Preventive Measures

More Effective Distribution Methods in Source Management

To maximize the performance of pollution prevention, source classification and management must be comprehensive. TSMC has put many resources into upgrading existing treatment equipment and constructing treatment facilities to direct to wastewater towards appropriate treatment systems and preliminarily degrade all pollutants. Following this, wastewater is condensed and reclaimed through the recycling system to further reduce the concentration of pollutants in line with the Company goals. Wastewater from manufacturing processes are distributed into several categories: hydrofluoric acid wastewater, acidic and caustic wastewater, chemical mechanical polishing (CMP) wastewater, and high-concentration liquid waste. All wastewater is stringently classified immediately at the tool. At total of 38 distribution systems have been established based on the composition and concentration of wastewater from manufacturing processes. In 2018, following changes to manufacturing processes, TSMC began to use cobalt as the material of choice for interconnect and installed a new distribution and treatment system for wastewater containing high concentrations of cobalt and cobalt-containing CMP wastewater. Manufacturing process wastewater can flow through distribution pipelines to be collected by different wastewater treatment facilities. TSMC has built a comprehensive wastewater classification and resourcing system and made much progress in acid-base neutralization systems and coagulation-precipitation systems. Since the beginning of development, each plant now has 9 recycling systems and 12 wastewater treatment systems. With robust classification and treatment techniques, all components in wastewater can be transformed into reusable resources.

Wastewater Classification and Recycling System

Tap water ▶ Processing equipment → Equipment Distribute → Recycling System → Wastewater Treatment → Recycling for Reuse → Recycling for reuse

Wastewater Treatment → Discharge to on-site wastewater treatment plants ▶ Rivers and the environment

	Equipment Distribute	Recycling System	Wastewater Treatment	Recycling for Reuse
Hydrofluoric (Hf) Acid Wastewater	• HF acid wastewater (2 types) • trioxygen-containing HF acid wastewater • manufacturing process scrubbing water	• hydrofluoric (HF) acid wastewater • tail gas scrubbing wastewater recycling	• chemical coagulation treatment of HF acid • HF (including ammonia) treatment • biological treatment of HF acid wastewater	• calcium fluoride • fluorite
Acidic, Caustic, and Organic Wastewater	• deionized water • trioxygen-containing deionized water • acidic wastewater (2 types) • trioxygen-containing acidic wastewater • Caustic wastewater • trioxygen-containing Caustic wastewater • TMAH wastewater • organic wastewater (2 types)	• acidic wastewater recycling • trioxygen-containing acidic wastewater recycling • Caustic wastewater recycling • Caustic wastewater upcycling • organic wastewater recycling	• acidic and Caustic wastewater treatment • NH4-N wastewater treatment and recycling • TMAH liquid waste recycling • biological treatment system for organic wastewater	• ammonium sulfate • ammonia water • gypsum • TMAH
CMP Wastewate	• electroplating wastewater • CMP wastewater (2 types) • copper-containing CMP wastewater • cobalt-containing CMP wastewater NEW	• chemical coagulation recycling of CMP wastewater • copper-containing CMP wastewater upcycling	• CMP wastewater treatment • copper-containing CMP wastewater treatment • cobalt-containing CMP wastewater treatment	
High-Concentration Liquid Waste	• Waste-CuSO4 • Waste-CoSO4 NEW • other wastewater (17 types)		• Waste-H2SO4 reclaim • copper-containing electroplating wastewater recycling	• sulfuric acid • copper bar • Cobalt bar

Note 1 TMAH stands for tetramethylammonium hydroxide
Note 2 Among all recycled products, sulfuric acid and electronic grade coating copper are reused in TSMC sites, while the rest are reused externally by other industries
Note 3 Categories of cobalt-containing wastewater and cobalt-containing liquid waste were added in 2018

Wastewater Discharge Monitoring

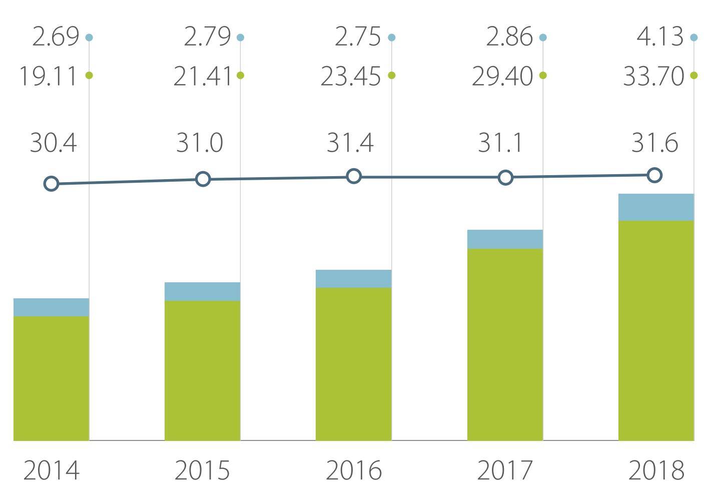
The amount of wastewater discharge is closely related to the volume of tap water consumption and water recycling. As TSMC's advanced process technology production continues to rise, unit water consumption, along with unit wastewater discharge, are increasing. TSMC has intensified its water recycling to reduce wastewater discharge. The discharge volume per product unit decreased by 2.4% from 2017 to 28.2 (liter / 8-inch e wafer-layer).

Wastewater Quality Improvement

All TSMC fabs have installed equipment to continuously monitor water quantity and quality at effluent spouts of wastewater treatment facilities. By closely monitoring and recording changes in water quality and quantity, TSMC can respond appropriately when abnormalities occur. TSMC not only follows statutory effluent water quality standards but also participates in eco-friendly activities. After assessing manufacturing raw materials by referencing domestic and international studies on biological toxicity, TSMC has focused on pollutants in the semiconductor industry, such as TMAH (strong base), copper ions (heavy metal) and ammonia, as well as suspended solids and chemical oxygen demands that directly impact marine life, setting these as key targets to be improved. The Company has carried out various improvement measures and reduced the impact of wastewater discharge on the environment.

38
The Industry's Strictest Wastewater Classification Management Systems

Wastewater Discharge Per Product Unit



Wastewater discharge of subsidiaries (Million metric tons)
Wastewater discharge in Taiwan facilities (Million metric tons)
Discharge Per Products Unit (liter / 8-inch e wafer-layer)

Note 1 Total wastewater volume included numbers from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), WaferTech, TSMC (China), TSMC (Nanjing), and VisEra
Note 2 Unit wastewater discharge intensity index is calculated with statistics from all TSMC wafer fabs and its subsidiaries

Preventive Techniques on Key Pollutants of Wastewater Quality and Improvement Achievements

Item	Standards set by Science Park Administration	TSMC Long-term Goals (2025)	Status in 2018	Improvement Achievements in 2018	Preventive Techniques
TMAH	HSP : 30 CTSP: 20 STSP: 60	1.0	13.1	Reduced by **57%** from the previous year	• Recycle low-concentration liquid waste • Establish anion exchange resin towers
copper ion	HSP : 1 CTSP: 0.8 STSP: 3	0.1	0.18	Reduced by **53%** from the previous year	• Distribute copper-containing liquid waste • Concentrate and recycle in resin towers (under planning)
NH4-N	HSP : 30 CTSP: 20 STSP: 60	20	21.0	Reduced by **87%** from the previous year	• Expand ammonia treatment systems
chemical oxygen demand	HSP : 500 CTSP: 500 STSP: 450	100	177.5	Raised by **47%** from the previous year	• Implement combustion treatment in strippers (under planning) • Establish biological treatment systems (Bioprocess) (under planning)
suspended solids	HSP : 300 CTSP: 300 STSP: 250	30	29.4	Achieved long-term goals ahead of schedule	• Recycle backwash wastewater after coagulation and precipitation

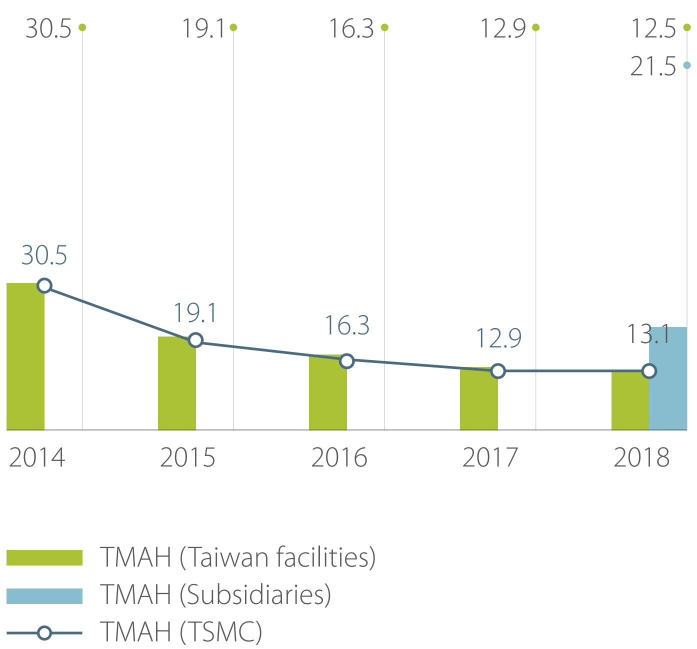
Unit: ppm

Note Hsinchu Science Park (HSP), Central Taiwan Science Park (CTSP), Southern Taiwan Science Park (STSP)

Pollutant Discharge Trends

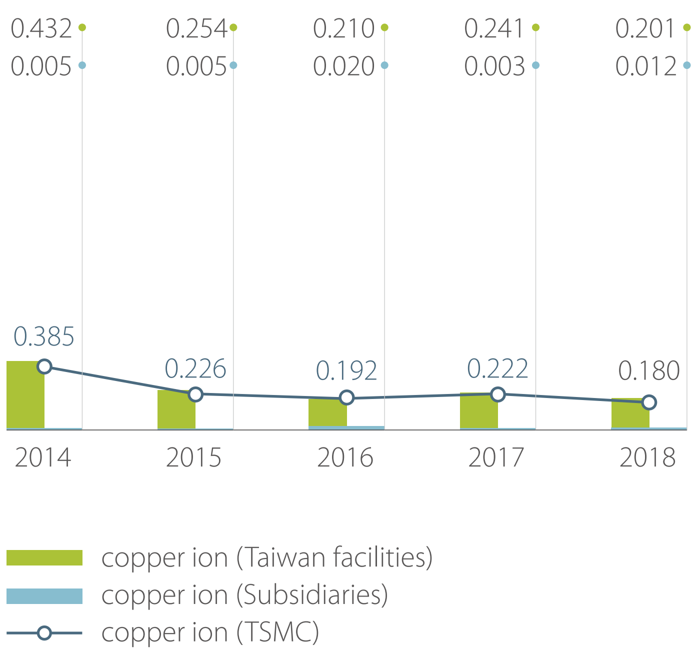
TMAH

Unit: ppm



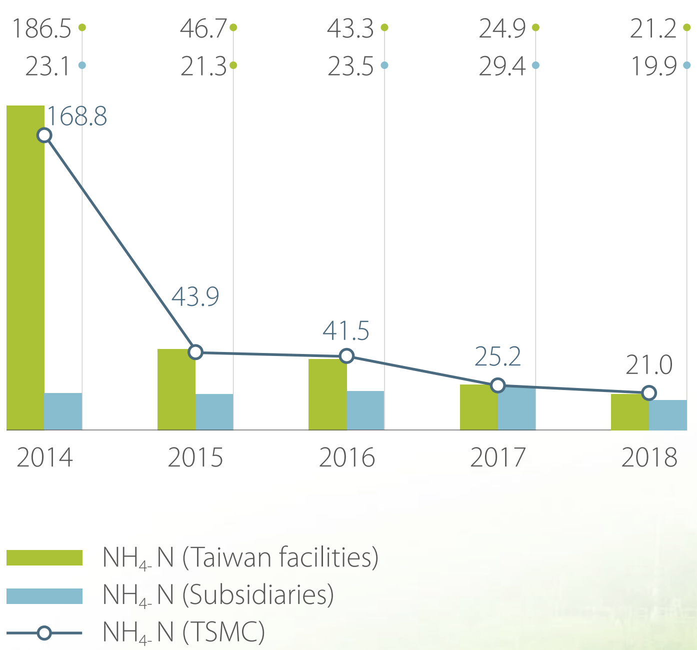
Cu^{2+}

Unit: ppm



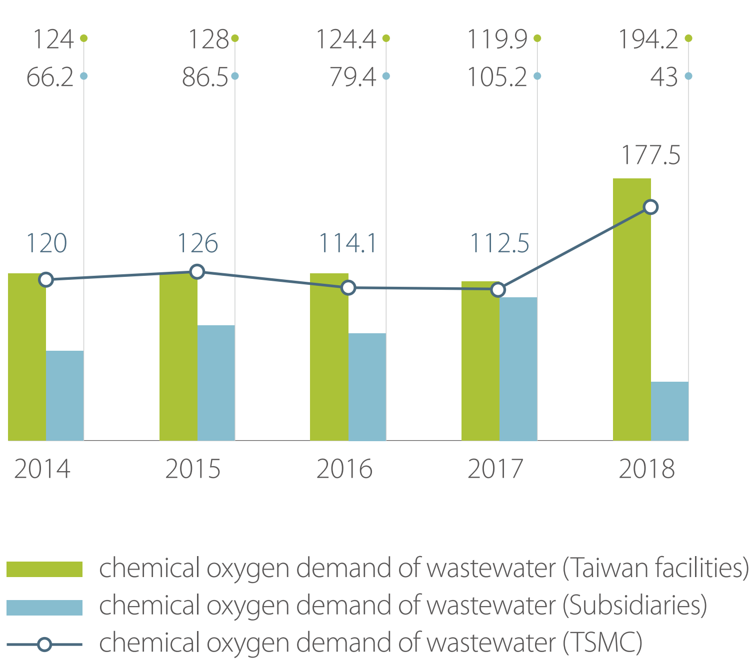
NH_4-N

Unit: ppm



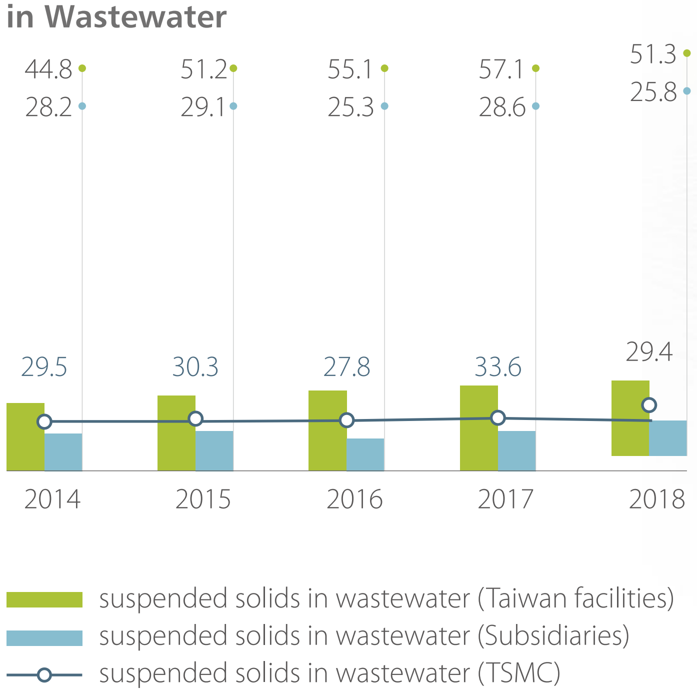
Statistics on the Chemical Oxygen Demand of Wastewater

Unit: ppm



Statistics on Suspended Solids in Wastewater

Unit: ppm



Note 1 Statistics of TMAH include data from TSMC (all wafer fabs and back-end assembly facilities), TSMC (China) and TSMC (Nanjing)

Note 2 Statistics of copper ions, chemical oxygen demand, and suspended solids in wastewater include data from TSMC's facilities in Taiwan (wafer fabs, testing and assembly plants), TSMC (China), TSMC (Nanjing), and VisEra

Note 3 Statistics of NH4-N include data from TSMC (all wafer fabs and back-end assembly facilities), TSMC (China), TSMC (Nanjing), VisEra, and WaferTech

Note 4 The 2018 statistics on the chemical oxygen demand of wastewater and suspended solids in wastewater are calculated with the weighted average of water volumes across all campuse

Note 5 Data for TSMC (Nanjing) were added in 2018

Case Study

Distribute Low-Concentration Wastewater and Reduce Chemical Use During Treatment

Appropriate water pollution prevention measures require considerations of treatment procedures and chemical dosage to effectively reduce target pollutants without increasing the discharge of other pollutants. In order to enhance the efficiency of copper capture, TSMC reduced its chemical dosage in treatment procedures and decreased the amount of copper sulfate liquid waste and chemical coagulation byproducts. After evaluating the raw material consumption and wastewater discharge status in 2018, TSMC included lower concentrations of copper-containing liquid waste (< 2 ppm) for treatment. The concentration of wastewater discharge is expected to decrease to 0.1mg / L by 2025 as a result of TSMC's unrivalled strict adherence to industry standards.

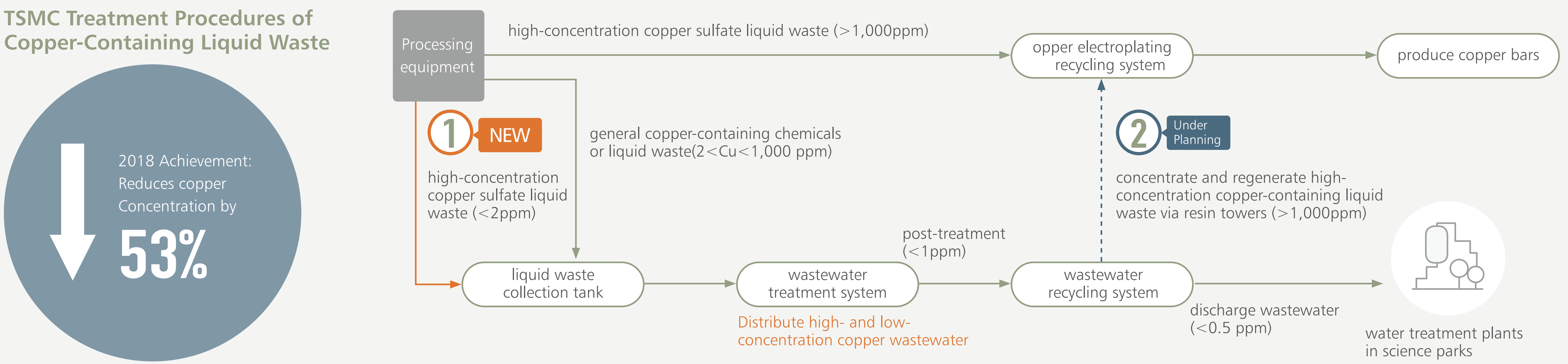
Repeated Examinations and Efficiency Enhancement of Mid- and Low-Concentration Wastewater Treatment

After approximately a thousand rounds of testing, examining, and analysis in 2018, TSMC has determined the optimal amount of chemicals for various concentrations and established two processes: recycling of low-concentration copper-containing chemicals and liquid waste, and the distribution of wastewater containing high-concentration coordination complex ions. Compared to 2014, these processes maximize the functions of a copper ion capturing agent (Cu chelating agent) while decreasing the concentration of copper from 3-4 ppm to less than 1 ppm, leading to an accumulated reduction of 53%. Additionally, the concentration of effluent water was reduced from 0.38 ppm to 0.18 ppm, much lower than the standards in all science parks and the copper ion standard of 1 ppm for drinking water.

Condensate Wastewater - Concentration, Recycling, and Copper Bar Production in Resin Towers

Based on wastewater treatment results in 2018, TSMC is actively conducting assessments and examinations for the establishment of a wastewater condensation and high-concentration copper regeneration and electroplating system in the hope that through resin and regeneration concentration selection and mixing tests, low concentrations of copper ions absorbed by the cation resin tower following regeneration and concentration by strong acids (hydrochloric acid) can be reclaimed as copper bars via electroplating. Through this measure, the treatment procedures for copper liquid waste can be further refined and become more eco-friendly.

TSMC Treatment Procedures of Copper-Containing Liquid Waste



Case Study

Comprehensive Collection and Double Treatment Reduces TMAH Concentration by 57%

Tetramethylammonium hydroxide (TMAH) is a strong alkali-containing neurotoxin commonly found in the wastewater of semiconductor manufacturing processes. TSMC has taken considerable efforts to capture TMAH through resin towers to mitigate its environmental impact. It has also cooperated with partner firms to reduce 25% concentrated TMAH into recyclable industrial-grade materials. In addition, TSMC has determined the optimal treatment curve for all fabs through long-term operation and continuous testing, thereby considerably reducing the amount of recycling by-products. To further decrease the concentration of TMAH, TSMC has extensively researched and analyzed the status of raw material use and waste discharge from equipment in 2018, following the two main guidelines of comprehensive collection and double treatment. In comparison to 2014, the average concentration of TMAH was reduced by 57% from 30.5 ppm to 13.1 ppm, and is expected to be reduced by 95% in 2025.

Comprehensive Collection: Inclusion of Low-Concentration Equipment Scrubbing Water

TSMC has established the most robust wastewater classification management system in the industry. It continues to improve the stability and efficiency of the system with thousands of parameter adjustments and resin category testing data every year. In 2018, the Company took a further step to collect and manage low-concentration liquid waste (TMAH<1,000 ppm). Instead of directly discharging the wastewater as before, pipelines for equipment scrubbing water were designed to recycle and manage the TMAH system in order to reclaim precious water resources.

Double Treatment: Recycle Regenerated Liquid Waste from Resin Towers

Cation resin towers are often used to absorb TMAH in the semiconductor industry. After saturable absorption, TMAH is regenerated during neutralization with strong acids. In the past, low-concentration TMAH acid could not be reabsorbed in the process due to sulfate ions (SO42-) and would often be discharged into wastewater. To resolve this issue, TSMC repeatedly examined and refined regeneration procedures until it successfully developed an anion resin tower mode, which takes regenerated liquid waste from resin towers and removes sulfate ions before introducing them into cation resin towers for effective absorption to further reduce TMAH concentration.

TSMC's Refined Procedures of TMAH Treatment