Basic Environmental Policy

As a comprehensive manufacturer of nonferrous metal resources and materials, JX Nippon Mining & Metals Group is carrying out the following initiatives aimed at contributing to environmental conservation on a global scale through innovation in the productivity of resources and materials.

Promotion of technology development that will improve productivity of resources and materials
We will work to utilize resources effectively by developing technologies that will enable higher yield and extraction percentage, quality improvement, shorter processing steps, recycling and energy savings, as well as developing environment-friendly materials and products.

Active engagement in environmental conservation
We will work to raise each employee’s awareness of environmental conservation and work actively and continuously for environmental conservation.

Disclosure of information
We will disclose the state of our environmental conservation-related operations in an active and fair manner in order to further enhance communication with stakeholders.

Enhancement of employees’ awareness of environmental conservation
We will work to raise each employee’s awareness of environmental conservation through provision of environmental management education.

Elimination of waste in operations
We will work to eliminate waste and save resources and energy at every stage of our operations.

Note on numerical data in this section
Due to rounding, numbers presented here may not add up precisely to the totals provided.

Action Plan for Environmental Protection

We have drawn up an Action Plan for Environmental Protection as outlined below, to implement the Basic Environmental Policy.

Approach to environmental protection

1. Environmental protection organization
The general manager of the Company’s Environment & Safety Department is in charge of coordinating and promoting environmental protection efforts in the Group. Recognizing that on-site personnel should be responsible for ensuring environmental protection, the top managers at each operating site serve as an executive environmental manager. At the same time, we are seeking to enhance the effectiveness of the Environment Measures Committees and to advance mutual understanding between labor and management regarding environmental protection.

2. Environmental management systems
Within the Group, management systems are operated at subsidiaries and overseas companies to promote continuous improvement and ensure the effective implementation of environmental protection measures. Environmental managers at each operating site serve as the chief environmental officers and conduct periodic environmental audits. In addition, the Environment & Safety Department’s environment and safety audit team conducts periodic environmental audits of each operating site, identifies problems and areas requiring remediation from an environmental management perspective, and continuously works to improve accident prevention and environmental conservation measures.

3. Environmental auditing
Supervisory environmental managers at each operating site review the results of internal audit to verify that risk management and compliance with environmental regulations are being maintained.

Measures to be taken

- Help prevent global warming
- Promote resource efficiency and recycling
- Reduce waste materials
- Manage chemical substances
- Maintain biodiversity
- Promote recycling services
- Develop environmentally friendly technologies and products
- Promote green purchasing
- Conduct training, public relations initiatives, and social activities to communicate our Action Plan for Environmental Protection and raise awareness of our environmental protection measures.

Environmental conservation at our overseas businesses

1. Environmentally friendly operations in our overseas business activities
We will further improve the environmental performance of our overseas business activities.

2. Environmentally friendly importing and exporting
In addition to adhering to the Basel Convention, we take steps to ensure that our importing and exporting partners do not harm the environment.

Environmental Targets

Along with the management in the 4th Medium-Term Action Plan, we are carrying out actions to meet the long-term targets for 2030.

- CO₂ Reduction and Energy Conservation: By fiscal 2030, reduction in CO₂ emissions by 18% from fiscal 1990 levels (a target set after the Japanese government’s new targets were incorporated in the Paris Agreement at COP21 in 2015)

Results for the 4th Medium-Term Action Plan (fiscal 2016 to 2019)

<table>
<thead>
<tr>
<th>Target area</th>
<th>Environmental targets</th>
<th>Performance in 2016</th>
<th>Performance in 2017</th>
<th>Summary</th>
</tr>
</thead>
</table>
| Energy and CO₂ | Cumulative allowable CO₂ emissions in Japan of less than 4.07 million tons for the four years from fiscal 2016 to 2019 | 853 thousand tons (Target achieved) | 858 thousand tons (Target achieved) | Due to energy-saving measures and other efforts, domestic CO₂ emissions in fiscal 2017 were 858 thousand tons, 161 thousand tons less than the single-year target of 1,019 thousand tons, achieving the target.
| Waste | Waste ratio of non-value-bearing waste volume*1 of less than 0.7% (ISO 14001) | *1 | *2 | *3 |
| Environmental management | Compliance with revisions to ISO 14001 (Environmental Management Systems) and scheduled implementation of compliance inspections and environmental auditing | *4 | *5 | *6 |
| Emissions from electricity usage are calculated using the coefficients stipulated by the Act on Promotion of Global Warming Countermeasures. Emissions from electricity usage are calculated using the coefficient of 0.417 tons of CO₂ per megawatt-hour (the actual figure for fiscal 1990 as given in the Environmental Action Plan of the Federation of Electric Power Companies of Japan) to reflect the efforts made by individual operating sites.

*1 Ratio of non-value-bearing waste volume / Volume of processed waste
*2 Volume of processed waste
*3 Target achieved
*4 Performance in 2016
*5 Performance in 2017
*6 Due to energy-saving measures and other efforts, domestic CO₂ emissions in fiscal 2017 were 858 thousand tons, 161 thousand tons less than the single-year target of 1,019 thousand tons, achieving the target.

Along with the management in the 4th Medium-Term Action Plan, we are carrying out actions to meet the long-term targets for 2030.

- CO₂ Reduction and Energy Conservation: By fiscal 2030, reduction in CO₂ emissions by 18% from fiscal 1990 levels (a target set after the Japanese government’s new targets were incorporated in the Paris Agreement at COP21 in 2015)

- Ratio of Non-Value-Bearing Waste Volume: By fiscal 2030, ratio of non-value-bearing waste volume of less than 0.5%
Environmental Management Systems

The JX Nippon Mining & Metals Group has established environmental management systems in line with ISO 14001 standards for ensuring achievement of the Action Plan for Environmental Protection, which was drawn up reflecting the Basic Environmental Policy. A multi-level organizational structure has been created, including various committees and subcommittees, in which everyone, from senior management headed by the president to employees at operating sites and affiliated companies, is working together to promote environmental conservation and avoid environmental risk.

Operating Sites That Have Obtained ISO 14001 Certification

Compliance with Environmental Laws and Regulations

Through the effective operation of environmental management systems at operating sites and affiliated companies, the Group is ensuring compliance with environmental laws and regulations. The Environment & Safety Department in the Head Office monitors and supervises the state of compliance and reports to the CSR Committee through the Safety and Environment Committee. The Group seeks to strengthen its compliance systems by such means as environmental manager meetings, held every year to share information on legal and regulatory trends and to hear compliance status reports from operating sites.

Environmental and Safety Auditing

Individual operating sites implement internal environmental audits at least once a year. In addition, they periodically undergo environmental and safety audits by the Environment & Safety Departments of the Head Office and of Pan Pacific Copper Co., Ltd. Audits were conducted at 12 sites in fiscal 2017.

Environmental Education

Periodic education, training, and drills are conducted for each employee level at the Head Office and individual operating sites, to spread awareness regarding the Basic Environmental Policy, the Action Plan for Environmental Protection, and applicable laws and regulations.

Transition to ISO 14001:2015

Of the 16 domestic operating sites that have acquired ISO 14001 certification, transition to the 2015 version was completed by 10 sites in fiscal 2017. The remaining six sites will complete the transition during 2018.

Environmental Management

Environmental Accidents

In fiscal 2017, there was one environmental accident, as indicated below. Necessary measures have been taken to address this accident and to make sure there is no recurrence.

<table>
<thead>
<tr>
<th>Date</th>
<th>Place</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 2017</td>
<td>Hitachi Works</td>
<td>Water leaked from a crack in a drainage thinner in the Dairin area, resulting in the flow of alkaline drainage water into the river system.</td>
</tr>
</tbody>
</table>

Environmental Assessment of Suppliers

The Group promotes environmental conservation in the entire supply chain including suppliers. Based on the Group’s Green Purchasing Guidelines, suppliers are asked to create an environmental management system to reduce their environmental impact. Additionally, green purchasing surveys are conducted periodically to confirm implementation by major suppliers. (See page 58 for details.)

Role of the Safety and Environment Committee

Activities in the areas of health and safety, and environmental protection, are planned, promoted, and reviewed by the Safety and Environment Committee, an organization under the CSR Committee, the Group promotes environmental conservation in the entire supply chain including suppliers. Based on the Group’s Green Purchasing Guidelines, suppliers are asked to create an environmental management system to reduce their environmental impact. Additionally, green purchasing surveys are conducted periodically to confirm implementation by major suppliers. (See page 58 for details.)

Principal products

- Copper concentrate: 92 thousand tons
- Refined copper: 654 thousand tons
- Gold: 34 tons
- Silver: 297 tons
- Platinum: 496 kilograms
- Palladium: 2,458 kilograms
- Other metals (selenium, tellurium): 308 tons
- Electro-deposited and treated rolled copper foil: 8 thousand tons
- Copper foil, special steel strips, etc.: 38 thousand tons
- Titanium sponge: 19 thousand tons
- Sulfuric acid (by-product): 1,577 thousand tons

Our Business Activities and the Environment

The JX Nippon Mining & Metals Group monitors and analyzes the impacts of its business activities on the environment and endeavors to reduce these impacts. An overview of our efforts in this area is given here.

Mass Balance Table for the Group (Fiscal 2017)

<table>
<thead>
<tr>
<th>Raw materials (1,000 tons)</th>
<th>Energy (terajoules)</th>
<th>Water resources (million cubic meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary raw materials</td>
<td>Fuel</td>
<td>Freshwater</td>
</tr>
<tr>
<td>Domestic operating sites</td>
<td>Domestic operating sites</td>
<td>4,066</td>
</tr>
<tr>
<td>Overseas operating sites</td>
<td>Overseas operating sites</td>
<td>2,167</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>Total</td>
</tr>
<tr>
<td>2,407</td>
<td>6,683</td>
<td>27.6</td>
</tr>
<tr>
<td>Recycled raw materials</td>
<td>Electricity</td>
<td>Seawater</td>
</tr>
<tr>
<td>Domestic operating sites</td>
<td>Domestic operating sites</td>
<td>13,592</td>
</tr>
<tr>
<td>Overseas operating sites</td>
<td>Overseas operating sites</td>
<td>8,675</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>Total</td>
</tr>
<tr>
<td>252</td>
<td>22,267</td>
<td>99.9</td>
</tr>
</tbody>
</table>

Producing domestic operating sites 3

Recycled raw materials

Domestic operating sites 249
Overseas operating sites 3
Total 252

Water resources (million cubic meters)

- Freshwater: 4,066
- Seawater: 13,592
- Total: 22,267

Emissions

- CO2 (1,000 tons)
  - Domestic operating sites: 276
  - Scope 1: 747
  - Scope 2: 406
  - Total: 1,602

- SOx (1,000 tons)
  - Domestic operating sites: 4.1
  - Overseas operating sites: 0.2
  - Total: 4.3

- NOx (1,000 tons)
  - Domestic operating sites: 0.6
  - Overseas operating sites: 0.2
  - Total: 0.8

Final disposal of waste materials

- Chemical substances (1,000 tons)
  - Domestic operating sites: 0.47

Wastewater

- Domestic operating sites: 156.4
- Overseas operating sites: 1.0
- Total: 157.4

For protecting the environment

JX Nippon Mining & Metals Corporation Sustainability Report 2018
Environmental Risk Management

Fundamental Policy

Air and water systems are key influencers of human health and living environments. In carrying out its business operations, the JX Nippon Mining & Metals Group gives top priority to protecting the environment relating to these two systems. In addition to abiding by all relevant laws, regulations, ordinances, and agreements, we have set and monitor our own voluntary standards to reduce environmental impact.

At the same time, we implement the plan-do-check-act cycle to reduce environmental risks.

Activity Results in Fiscal 2017

Preventing Air Pollution

The Group monitors waste gas emissions at all operating sites in compliance with laws, regulations, ordinances, agreements, and voluntary standards. In fiscal 2017, emissions of both sulfur oxides (SOx) and nitrogen oxides (NOx) in the Group decreased from fiscal 2016 levels. Principal reasons for the decline in SOx emissions were the reduced number of operating days at the Sagasenoki Smelter & Refinery of Pan Pacific Copper due to regular maintenance, and the improvement in desulfurization rate at the sulfuric acid plant of Hibi Kyodo Smelting. The latter is the reason for the reduction in SOx emission intensity.

Preventing Water Pollution

The Group monitors water discharge at all operating sites in compliance with laws, regulations, ordinances, agreements, and voluntary standards. The COD1 and BOD2 levels are shown below.

<table>
<thead>
<tr>
<th>Year</th>
<th>COD (kmol/ton)</th>
<th>BOD (kmol/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>4.6</td>
<td>0.2</td>
</tr>
<tr>
<td>2014</td>
<td>5.4</td>
<td>0.2</td>
</tr>
<tr>
<td>2015</td>
<td>5.1</td>
<td>0.2</td>
</tr>
<tr>
<td>2016</td>
<td>7.2</td>
<td>0.2</td>
</tr>
<tr>
<td>2017</td>
<td>4.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*1 Total of total of operating sites subject to emissions regulations.

SOx Emissions

<table>
<thead>
<tr>
<th>Year</th>
<th>Total of total of operating sites (kt)</th>
<th>Total of overseas operating sites (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>64</td>
<td>126.2</td>
</tr>
<tr>
<td>2014</td>
<td>100</td>
<td>126.2</td>
</tr>
<tr>
<td>2015</td>
<td>91</td>
<td>126.2</td>
</tr>
<tr>
<td>2016</td>
<td>99</td>
<td>126.2</td>
</tr>
<tr>
<td>2017</td>
<td>100</td>
<td>126.2</td>
</tr>
</tbody>
</table>

*2 Total of total of operating sites subject to legal requirements.

SOx Emission Intensity at Smelters and Refineries

(kilograms/ton)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total of operating sites</th>
<th>Total of overseas operating sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>2014</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>2015</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>2016</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>2017</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

NOx Emissions

<table>
<thead>
<tr>
<th>Year</th>
<th>Total of total of operating sites (kt)</th>
<th>Total of overseas operating sites (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>2014</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>2015</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>2016</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>2017</td>
<td>0.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*1 Total of total of operating sites subject to emissions regulations.

NOx Emission Intensity at Smelters and Refineries

(kilograms/ton)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total of operating sites</th>
<th>Total of overseas operating sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>2014</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>2015</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>2016</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>2017</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

*2 Total of total of operating sites subject to legal requirements.

Environmental Risk Management

At operating sites with significant release and transfer of chemicals, the Group strictly adheres to the Act on Confirmation, Etc., of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof (PRTR Act). Also, as part of our environmental management activities, we are working to reduce our environmental impact by setting targets for decreasing the release and transfer volumes of applicable chemical substances.

Volumes of Release and Transfer of PRTR Substances

Release volume

Transfer volume

<table>
<thead>
<tr>
<th>Substances</th>
<th>Release volume (kt)</th>
<th>Transfer volume (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Antimony and its compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Cadmium and its compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Copper and its compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Lead compounds</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Arsenic and its inorganic compounds</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Mercaptans</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Polychlorinated CBs (PCBs)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Bromocyclopentadibenzofuran</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Bromoform</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lead compounds</td>
<td>0.0</td>
<td>0.0</td>
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</tr>
<tr>
<td>Chloroform</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*1 Total of total of operating sites subject to reporting according to the PRTR Act.

Volumes of Release and Transfer of Major PRTR Substances in Fiscal 2017 (grams of toxic equivalents)

<table>
<thead>
<tr>
<th>Chemical substance</th>
<th>Release volume (grams)</th>
<th>Transfer volume (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Antimony and its compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Cadmium and its compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Copper and its compounds</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Lead compounds</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>Arsenic and its inorganic compounds</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Mercaptans</td>
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<td>Polychlorinated CBs (PCBs)</td>
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<tr>
<td>Bromocyclopentadibenzofuran</td>
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<td>0.0</td>
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<tr>
<td>Bromoform</td>
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<td>0.0</td>
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<td>Chloroform</td>
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</tr>
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<td>Toluene</td>
<td>0.0</td>
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<td>Chloroform</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*1 Total of total of operating sites subject to reporting according to the PRTR Act.

Breakdown of Release Volumes of PRTR Substances

Volume: 0.08

Release volume

Transfer volume

<table>
<thead>
<tr>
<th>Substances</th>
<th>Release volume (kt)</th>
<th>Transfer volume (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc compounds</td>
<td>0.1</td>
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<td>0.0</td>
</tr>
</tbody>
</table>

*1 Total of total of operating sites subject to reporting according to the PRTR Act.

Detoxification of PCB-Containing Equipment

The Group carries out disposal of equipment containing high concentrations of PCBs, using the services of Japan Environmental Storage & Safety Corporation. Disposal is expected to be completed during 2018, with the exception of operating sites in Tokyo and Kanagawa where treatment is behind schedule.

We have also been detoxifying equipment containing low concentrations of PCBs by entrusting a private-sector facility under a systematic program that began in fiscal 2012. In March 2014, JX Nippon Tomakomai Chemical received certification from the Minister of the Environment to provide a low-concentration PCB waste treatment service, and carries out detoxification of Group equipment containing low concentrations of PCBs.

Compliance with the REACH Regulation

The European Union’s Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH Regulation) came into effect in June 2007. Based on precautionary principles, the purpose of this regulation is to standardise the management and identification of chemicals that are distributed within the EU, and to monitor their risks and clarify their environmental impact. The Group respects the intent of the REACH Regulation, and has completed preliminary registration of products that are subject to the regulation.
Environmental Management

Management of Closed Mines

From its founding in 1905, the JX Nippon Mining & Metals Group was engaged in mining operations across Japan. By ensuring a steady supply of nonferrous metals and other resources, we contributed to Japan’s economic growth. Today, however, nearly all the mining operations have been stopped due to the depletion of mineral resources. Currently, the Group is working to maintain and restore the natural environment in and around the closed mines. One such effort is the treatment of acid mine drainage (AMD).

Management Work at Closed Mines

Of the 39 closed mines managed by the Company, AMD treatment is an ongoing obligation at 12 mines pursuant to the Mine Safety Act. JX Nippon Mining Ecomanagement is responsible for the work at these mining sites, including AMD treatment and the management of tailings dams.

The work mainly consists of treating the highly acidic mine drainage generated from the mines and tailings dams, which contain heavy metals, and maintaining and preserving the tailings dams and galleries of the mining sites.

The operation of treatment facilities has to be kept up 365 days a year, since AMD is generated continuously after a mine is closed. This is a result of the chemical reaction of rainwater and other water with ores remaining in the mine and tailings in the dams.

How AMD Occurs

AMD from closed mines consists of pit water rising up from inside the mine and effluent discharged from tailings dams or other mine facilities. It occurs as a result of rainwater and other water coming into contact with materials such as ores remaining after the mine is closed, the nearby altered rock, and flotation tailings that have accumulated in the dams. These ores and altered rock contain iron, zinc, manganese, and other metals in the form of sulfide minerals, as a result of bonding with sulfur. These sulfide minerals are oxidized in the presence of oxygen and dissolve in water in the form of metal ions, hydrogen ions, or sulfuric acid ions, causing the drainage water to become highly acidic.

Construction Work to Protect Tailings Dams from Earthquakes and Torrential Rain

After the Great East Japan Earthquake, starting in fiscal 2012 we began conducting voluntary risk assessments of all tailings dams under management of the Group relative to a Level 2 earthquake (seismic motion of the maximum intensity conceivable for the particular area both now and in the future). At the same time, we assessed their stability to localized torrential rain of the kind that has become increasingly common in recent years, as well as the possible downstream impact of the outflow of tailings from the dams.

After determining the risks by means of these voluntary inspections, we set priorities for those tailings dams identified as requiring further measures and began the necessary construction work starting in fiscal 2013.

The construction work includes soil stabilization to ensure earthquake resistance and building new drains to obtain sufficient drainage capacity during torrential rain.

1. Locations of Countermeasures Implemented in Fiscal 2017

<table>
<thead>
<tr>
<th>Earthquake-related:</th>
<th>Hanawa Mine, Nakanoosawa Tailings Dam (downstream method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrential rain-related:</td>
<td>Namariyama Mine, Oyu 1st and 2nd Tailings Dams (upstream method)</td>
</tr>
</tbody>
</table>

2. Locations of Countermeasures Planned for Fiscal 2018

<table>
<thead>
<tr>
<th>Earthquake-related:</th>
<th>Namariyama Mine, waste rock storage facility (ongoing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrential rain-related:</td>
<td>Mitate Mine, Sangoosawa Tailings Dam (upstream method)</td>
</tr>
<tr>
<td></td>
<td>Kawazu Mine, Horinouchi Tailings Dam (upstream method)</td>
</tr>
<tr>
<td></td>
<td>Kawayama Mine, 2nd Tailings Dam (downstream method)</td>
</tr>
</tbody>
</table>

Upstream Method (raising embankment height)

Downstream Method
Establishing a Low-Carbon Society

Since the Paris Agreement was adopted at the COP21 United Nations Conference on Climate Change, there have been increasing demands on corporations to become actively involved in reducing emissions of greenhouse gases through such means as setting long-term reduction targets.

The JX Nippon Mining & Metals Group seeks to reduce the environmental burden of its business pursuits as much as possible. Our Basic Environmental Policy goes beyond compliance with environmental regulations, calling for development of energy-saving technology to help prevent global warming. We make clear our management of environmental targets in our Medium-Term Action Plan and elsewhere, endeavoring to reduce our environmental burden each fiscal year.

Energy Conservation

Fundamental Policy

Global warming is bringing about frequent abnormal weather, rising sea levels due to changing climate patterns, and other impacts. Furthermore, it is feared that the significant impact on ecosystems may undermine the sustainable development of society as a whole.

The JX Nippon Mining & Metals Group has defined long-term targets for reducing emissions of CO2 and other greenhouse gases, which we are pursuing by promoting energy conservation and expanding the use of renewable energy. (See page 60 for details.)

Activity Results in Fiscal 2017

Energy Consumption and Energy Consumption Intensity in Manufacturing Activities

In fiscal 2017, the Group’s overall energy consumption in terms of its calorific value was 28,950 terajoules,* compared with 28,778 terajoules in fiscal 2016. The further rise in the Caserones Copper Mine operating rate was one of the major factors resulting in an increase of 172 terajoules. Around 48% of the Group’s total energy consumption at operating sites in Japan is accounted for by energy consumed at smelters and refineries, where energy consumption intensity in fiscal 2017 remained at around the same level as in the previous fiscal year. The Group will continue to take active measures for reducing energy use and improving efficiency. As an example of such measures, at the Tamano Smelter of Hibi Kyodo Smelting, the oxygen production systems were upgraded to a single system adopting the latest technology. The resulting improved energy efficiency led to a reduction in electricity usage by a total annual calorific value of 275 terajoules. At the Saganoseki Smelter & Refinery of Pan Pacific Copper, steam loss was reduced by a total annual calorific value of 33 terajoules, by making sure steam traps were regularly inspected and replacing defective traps.

At our overseas operating sites as well, we are taking steps to reduce energy consumption, such as optimizing the number of cooling towers in operation, installing pump-inverter control equipment, introducing high-efficiency air conditioners, and carrying out phased replacement of conventional lighting with LED lamps. We will continue to pursue additional reductions in energy use and improve waste heat recovery by installing energy-efficient equipment.

* Energy consumption is calculated using coefficients in accordance with the Act on Rationalizing Energy Use, for both domestic and overseas operating sites.

A breakdown of energy consumption is shown below (terajoules).

<table>
<thead>
<tr>
<th>Year (FY)</th>
<th>Electricity (indirect): Domestic</th>
<th>Overseas</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>13,592</td>
<td>8,675</td>
</tr>
<tr>
<td>2014</td>
<td>13,942</td>
<td>9,142</td>
</tr>
<tr>
<td>2015</td>
<td>13,986</td>
<td>8,752</td>
</tr>
<tr>
<td>2016</td>
<td>13,875</td>
<td>11,852</td>
</tr>
<tr>
<td>2017</td>
<td>13,802</td>
<td>12,362</td>
</tr>
</tbody>
</table>

Fuel (direct)

<table>
<thead>
<tr>
<th>Year (FY)</th>
<th>Kerosene (kl)</th>
<th>Light oil (kl)</th>
<th>Class A heavy oil (kl)</th>
<th>Class B and C heavy oil (kl)</th>
<th>Reclaimed oil (kl)</th>
<th>LPG/butane (t)</th>
<th>LNG (t)</th>
<th>Coke (t)</th>
<th>Petroleum coke (t)</th>
<th>City gas (1,000 m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>1,982</td>
<td>2,645</td>
<td>9,253</td>
<td>43,502</td>
<td>1,941</td>
<td>5,133</td>
<td>4,839</td>
<td>9,074</td>
<td>2,977</td>
<td>16,467</td>
</tr>
<tr>
<td>2014</td>
<td>2,125</td>
<td>2,848</td>
<td>9,263</td>
<td>43,502</td>
<td>2,015</td>
<td>4,839</td>
<td>4,839</td>
<td>9,074</td>
<td>2,977</td>
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<td>9,074</td>
<td>2,977</td>
<td>16,467</td>
</tr>
</tbody>
</table>

Note: A terajoule is one trillion joules, a unit of energy.

Establishing a Low-Carbon Society

For protecting the environment

Material Issues

Establishing a Low-Carbon Society

For protecting the environment

Material Issues

Oxygen production system at Tamano Smelter, Hibi Kyodo Smelting
Energy Conservation

CO2 Emissions from Energy Consumption for Manufacturing Activities

In fiscal 2017, the Group’s total CO2 emissions from energy consumption in Japan and overseas were 1,602 thousand tons of CO2. There was a slight rise in CO2 emissions from energy consumption over fiscal 2016, resulting from a higher operating rate at the Caserones Copper Mine.

Approximately 48% of the Group’s total energy consumption in Japan is accounted for by energy consumed at smelters and refineries. Through the consolidation of facilities, improved production efficiency, and other measures, the Group reduced CO2-emission intensity at these sites to 0.86 in fiscal 2017, down approximately 40% from 1.34 in fiscal 1990.

Expansion of Renewable Energy Usage

Hydroelectric power generation in the Group traces back to 1907, when its predecessor Kuhara Mining operated. Today, we carry out power generation operations at the Kakinosawa Hydroelectric Power Plant and sell the electricity generated to specified-scale electricity utilities. From October 2014 to June 2015, the facilities of the Kakinosawa Hydroelectric Power Plant were upgraded to enable more effective use of valuable water resources. The plant is now operating stably with increased power generation capacity thanks to upgraded facilities such as turbines, generators, and power receiving and transforming equipment. A photovoltaic power generation facility with capacity of 240 kilowatts went into operation in April 2013 at the Kakegawa Works of JX Metals Precision Technology, Ltd. At Shimoda Hot Springs, a binary power generation system making use of heat from hot springs was installed, going into operation in March 2018. Photovoltaic power generation is also carried out at the Hibi Smelter of Pan Pacific Copper.

CO2 Emissions Other than from Energy Consumption, and Other Greenhouse Gas Emissions from Manufacturing Activities

Three operating sites in the recycling and environmental services business submit reports on the emissions of CO2 from sources other than energy consumption as well as the emissions of other greenhouse gases. In fiscal 2016, such emissions totaled approximately 57 thousand tons of CO2. In fiscal 2017, this amount grew by 37 thousand tons to around 94 thousand tons of CO2 (consisting entirely of CO2 emissions from sources other than energy consumption).

Results in Fiscal 2017

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Total generated electricity (megawatt-hours)</th>
<th>Generated electricity sold (megawatt-hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroelectric power</td>
<td>26,690</td>
<td>26,638</td>
</tr>
<tr>
<td>[Kakinosawa Power Plant]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photovoltaic power</td>
<td>684</td>
<td>674</td>
</tr>
<tr>
<td>[Kakegawa Works]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For protecting the environment

Establishing a Recycling-Oriented Society

The JX Nippon Mining & Metals Group seeks to reduce the environmental burden of its business pursuits as much as possible. Our Basic Environmental Policy calls for conserving resources, promoting recycling, and reducing waste materials. We therefore take steps to use recycled resources as raw materials, utilize by-products, and reduce the volume of final disposal by recycling waste materials.
Establishing a Recycling-Oriented Society

Initiatives for Effective Resource and By-Product Use and Waste Reduction

**Fundamental Policy**

The JX Nippon Mining & Metals Group is committed to helping prevent the depletion of natural resources and reducing the discharge of waste materials. We therefore strive to make effective use of water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste. The Group also strives to effectively utilize water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste materials. We therefore strive to make effective use of water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste. The Group also strives to effectively utilize water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste.

**Activity Results in Fiscal 2017**

**Usage of Recycled Resources as Raw Materials**

The Group used recycled resources to expand usage of recycled resources as raw materials in fiscal 2017. The major driving force behind this increase was the increase in volume of final disposal at the Caserones Copper Mine.

**Reuse and Reduction of Waste Materials**

The Group used recycled resources as raw materials to reduce waste materials. The Group therefore strives to make effective use of water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste.

**Volume of Final Disposal of Waste Materials**

The Group used recycled resources as raw materials to reduce waste materials. The Group therefore strives to make effective use of water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste.

**Total Volume of Waste and Sellable Materials Generated**

The Group used recycled resources as raw materials to reduce waste materials. The Group therefore strives to make effective use of water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste.

**Total Discharge Volume by Type of Waste Materials**

The Group used recycled resources as raw materials to reduce waste materials. The Group therefore strives to make effective use of water resources, use recycled resources as raw materials, utilize by-products, and further reduce waste.

**Use of By-Products**

In fiscal 2017, the Group produced 3,213 thousand tons of by-products. Slag is utilized as a sandblasting material, a cement material, a caisson filler, or as an aggregate for wave-dissipating blocks. Iron concentrate and gypsum are used in cement.

**Effective Use of Water Resources**

Of the Group’s water usage in fiscal 2017, seawater accounted for 78% of the total. Of the volume of water discharged into the sea, water usage at domestic operating sites in fiscal 2017 decreased 10% year on year. Overseas, water usage decreased 30% year on year.

**Water Usage**

- Total usage: 127.9 million cubic meters
- Total discharge: 121.6 million cubic meters

**Water Discharge Volume**

- Total discharge: 127.5 million cubic meters

**Water Usage Intensity at Smelters and Refineries**

- (cubic meters per ton of refined copper produced)
  - Total of domestic operating sites: 142.3
  - Total of overseas operating sites: 144.4

**Water Discharge Intensity at Smelters and Refineries**

- (cubic meters per ton of refined copper produced)
  - Total of domestic operating sites: 157.4
  - Total of overseas operating sites: 157.4

*1 These figures do not include the approximately 26.1 million tons of slag from the Caserones Copper Mine.

*2 These figures do not include the approximately 30.1 million tons of slag from the Caserones Copper Mine.
JX Nippon Mining & Metals is taking part in the Tokyo 2020 medal project conducted by the Tokyo Organising Committee of the Olympic and Paralympic Games, through NTT Docomo, Inc. and the Japan Environmental Sanitation Center (JESC), which are co-operating in the project. The Group, having long directed its business activities at building a recycling-oriented society, supports the purpose of this project to help build a sustainable society. It is hoped that this project will be an occasion for the general public to become aware of the importance of recycling nonferrous metals, and that it will give impetus to worldwide efforts to recycle resources.

About the Tokyo 2020 Medal Project

The Tokyo Organising Committee of the Olympic and Paralympic Games is conducting the Tokyo 2020 medal project to manufacture the medals for use at Tokyo 2020 from small electronic devices such as discarded mobile phones. Through this project, the committee plans to have approximately 5,000 gold, silver, and bronze medals made for the Olympic and Paralympic Games.

Role of the Group

1. The JX Nippon Mining & Metals Group is using its smelting, refining, and metal processing technologies to produce silver and bronze as medal materials from the recycled materials provided by NTT Docomo and the JESC.

Smelting, Refining, and Processing of Bronze Medal Material

Red brass, a copper and zinc alloy used as the material for bronze medals, is manufactured in sheet form. After the recycled material has undergone smelting and refining to produce refined copper at the Saganoseki Smelter & Refinery and Hitachi Refinery of Pan Pacific Copper, the copper is mixed with zinc and alloyed at the Kurami Works, where it is also put through hot rolling and other processes.

2. JX Metals Trading and JX Nippon Tsuruga Recycle have been contracted by the JESC to collect small electronic devices for this project as accredited recyclers under the Act on Promotion of Recycling of Small Waste Electrical and Electronic Equipment.

3. We are cooperating in the collection efforts by placing boxes throughout Japan for collecting mobile phones and small appliances.

Using Nonferrous Metal Resources Effectively

Nonferrous metals such as copper, used in electrical wires and electronic materials, are essential resources on which the abundant life enjoyed by modern society depends, yet their reserves are finite.

As stated in our Code of Conduct, the JX Nippon Mining & Metals Group promotes recycling to achieve zero emissions while continuing to pursue technical rationality and efficiency and to make improvements in product quality and properties. In such ways, we are continually targeting innovation in the productivity of resources and materials. Through ongoing product and technology development and outside collaboration, among other means, we seek the innovation that will ensure nonferrous metal resources can be used effectively and provide greater convenience.

At JX Nippon Mining & Metals, we have formed a Technology Council as an advisory body to the president. It discusses future possibilities for technology overall, including this topic, from the standpoint of business administration.
Developing Resources by the JX-Iodine Process

Reserves of copper and other nonferrous metals, while essential to the abundant life of contemporary society, are finite. Mines today are increasingly developed at higher elevations and in more remote locations, while the grade of ores is declining. Another problem is rising resource nationalism in various parts of the globe. As a result, even greater importance than before is being attached to effective resource use. In our resources development business and smelting and refining business, the Group is pursuing the efficient mining, concentration, and refining of copper ores, seeking effective use of limited nonferrous metal resources.

Background

Over the years, the grade of copper ores available throughout the world has been declining. Much of the copper ore mined these days is low-grade ore of less than 1% copper content. Low-grade ores for which ordinary flotation processes are not economically feasible have therefore not been exploited as resources. Among these, primary copper sulfide ores have been considered particularly difficult ores from which to leach out the copper.

We developed the JX-Iodine process as an original technology for efficiently leaching and recovering copper from these ores, and are moving closer to commercialization.

The JX-Iodine Process

This is a relatively simple process for oxidative leaching of copper from primary copper sulfide ores. Key features of the process are the addition of iodine as a catalyst and use of iodine recovery equipment along with the SX-EW equipment used for conventional heap leaching. While taking advantage of the technological features, the process complies with various environmental regulations and is designed with due consideration for environmental protection.

The JX-Iodine process is original technology that will contribute to effective use of limited copper resources and their stable and efficient supply, while bringing a technological advantage to the resources development business of JX Nippon Mining & Metals.

Current Assessment of Feasibility and Future Outlook

For approximately one year starting in 2014, we conducted heap-leaching experiments in Chile using the JX-Iodine process, verifying its commercial feasibility and effectiveness in improving copper leaching performance. Currently, we are preparing for on-site verification tests at mines and with ores for which the technology promises to be most effective.

Endowed Research Unit for Nonferrous Metal Resource Recovery Engineering (JX Metals Endowed Unit)

In recent years, the number of researchers and engineers in Japan working in fields related to smelting, refining, and recycling nonferrous metals has been continually decreasing. In response to this situation, JX Nippon Mining & Metals, in collaboration with the Institute of Industrial Science, the University of Tokyo, launched the Endowed Research Unit for Nonferrous Metal Resource Recovery Engineering (JX Metals Endowed Unit) with the aim of unifying the forces of industry, government, and academia toward energizing the industry and raising the level of its efforts.

In the Endowed Unit, these unified forces have been carrying out various initiatives, from using and extending smelting and refining technologies to develop new environment-friendly recycling technologies for nonferrous base metals and rare metals, to developing the human resources in charge of the work in this field.

Overview of Activities

A major focus of activities in Phase 1, which began in January 2012, was on providing various opportunities for learning about nonferrous metals. During the five-year period, symposiums and workshops were held nine times, attended by a total of 1,600 persons from industry, government, and academia. As a result of these activities, the Endowed Unit can now be seen as one of Japan’s leading platforms built through industry-government-academia collaboration in the field of nonferrous metal smelting, refining, and recycling.

Phase 2, started in January 2017, continues the Phase 1 initiatives, while also emphasizing public relations to highlight the importance and future potential of the nonferrous metals field to the general public, especially young people of high school age and below. The aim is to secure the human resources who will lead the next generation and thereby contribute to the creation of a recycling-oriented society. In addition, the unit is actively engaging in new initiatives, including collaboration with other universities.
Endowed Research Unit for Nonferrous Metal Resource Recovery Engineering

(JX Metals Endowed Unit)

Examples of Activities in Fiscal 2017

Activities Aimed at High School Students

“Friday Special Lecture for High School Students” (May 2017)
At this lecture, held by the College of Arts and Sciences of the University of Tokyo, Professor Okabe gave a presentation titled “Future Materials: Titanium and Rare Metals.” More than 150 persons were in attendance at the lecture, which was also live on the Internet to 37 high schools throughout Japan. Professor Okabe went beyond talking about rare metals and other nonferrous metals, carefully explaining such matters as the difference between “science” and “engineering” in academic fields.

Extension Special Lecture for High School Students (July 2017)
This lecture, organized by the Kanto Branch of the Society of Chemical Engineers, with the joint support of the Faculty of Science and Engineering, Waseda University, and the JX Metals Endowed Unit, was attended by more than 50 high school students. In Part 1, Professor Tokoro gave a presentation on separation technologies for extracting metal resources, and on applications of high school science to actual society. Part 2 started off with an experiment in which metal ions were identified in a solution prepared in advance. The participants tried to determine the metal using the reagent reaction as a clue. Students then toured the laboratories and facilities as they learned about the importance and appeal of this field of study.

Activities Aimed at Primary and Middle School Students

Exhibit at “UniLab” (August 2017)
At the UniLab (University Laboratory) event, an experimental science class for primary and middle school students held by the Faculty of Science and Engineering of Waseda University, a joint exhibit was presented by the research laboratory of Professor Tokoro and the JX Metals Endowed Unit, where third- and fourth-graders could experiment with gold-plating on copper sheets. The experiment piqued the interest of participants. They thought about the electrical conductivity of materials to choose the electrode for plating, and to affix seals on copper sheets to see the difference between plated and non-plated areas.

Special Lecture in Higashimatsuyama, Saitama Prefecture (November 2017)
At this lecture event put on by the Board of Education in Higashimatsuyama City, Professor Okabe spoke to an audience of around 700 of the city’s second-grade middle school students on the theme, “Future Materials: Titanium and Rare Metals.” His explanations covered examples of nonferrous metals used in familiar places, such as the titanium roof tiles of Tokyo’s Sensoji temple, as he spoke passionately about the importance of rare metals and other nonferrous metals.

Activities and Symposium for the General Public

Booth Display at the University of Tokyo’s Komaba Research Campus Open House (June 2017)
At the two-day Open House, the Company, and the JX Metals Endowed Unit, collaborating with the university’s Office for the Next Generation (ONG), presented an experimental booth display. Along with displays of copper ores, refined copper, and examples of copper plated and non-plated areas.

Symposium on Minor Metals in Nonferrous Metal Smelting (November 2017)
Nine lecturers from industry, academia, and government were invited to speak at the convention hall of the Institute of Industrial Science, the University of Tokyo. Around 160 persons attended the event, which featured distinguished talks and active discussions on the future vision and challenges of mining, production and recycling of minor metal resources, such as molybdenum, rhodium, and bismuth, which are by-products of nonferrous metal smelting and refining processes.

Participants looking at reagent reaction

Lecture by Professor Okabe

Plating experiment

Lecture by Professor Okabe

Lecture in progress at the symposium

Toward the Advancement of the Nonferrous Metals Industry

JX Nippon Mining & Metals established the Endowed Research Unit for Nonferrous Metal Resource Recovery Engineering (JX Metals Endowed Unit) in collaboration with the Institute of Industrial Science of the University of Tokyo. Phase 2 has been underway since January 2017. We held a roundtable discussion with Professor Chiharu Tokoro of Waseda University, newly appointed as Project Professor in Phase 2, for a roundtable discussion. (June 2019, in Tokyo)

Issues for the Nonferrous Metals Industry

Komatsuzaki To begin, I would like to ask you to talk about current issues for the nonferrous metals industry as seen from the corporate standpoint and from the university standpoint.

Yuki Six years since the start of the Endowed Unit, let me first of all take a look back at Phase 1. There were two objectives in starting the unit. The first was to help create a recycling-oriented society through surveys and research on the engineering for recycling metal materials essential to industry. The second was to contribute in the long term to human resource development in a wide range of related fields, not limiting the efforts to one university and one corporation, and to form a base for leading-edge research and industry-academia collaboration. Human resource development, not limited to one university and one corporation, was seen as an important issue from the start.

Among the major achievements of the five years of activities in Phase 1 were the symposiums we held, each time gathering more than 200 professionals from industry, government, and academia. I believe that even the students and young researchers who viewed these events up close could appreciate that they were extremely lively, but at the same time we were keenly aware of the limits to the role of symposiums.

As computers have progressed in recent years, electronic parts and devices have taken on highly advanced functions. And the development and supply of the leading-edge materials used in these parts and devices relies on high-purity, high-quality nonferrous metals. Even so, young people show little interest in materials or the nonferrous metals industry, and the number of university researchers and courses related to nonferrous metals has been decreasing. From the corporate standpoint, we feel a strong sense of impending crisis: unless we break out of this situation, the supply of advanced functional materials will be come hard to maintain.

Sustained growth of the materials industry requires securing human resources to support it. As I mentioned earlier, we have seen human resource development as an important issue. In order to develop human resources, however, you have to first secure human resources to develop. Thinking that approaching students at the university level may be too late, therefore, in Phase 2 our focus turned to helping primary, middle, and high school students, and their parents to understand the importance and appeal of the industry.

Tokoro I watched the Phase 1 activities from the sidelines and felt that the high quality of the symposiums provided wonderful opportunities for networking and exchanges in our field. It is also true that the university students were stimulated by these opportunities. The university is gradually becoming more successful at conveying the appeal of this field to students who...
Discussion Participants

Chiharu Tokoro
Professor, Faculty of Science and Engineering, Waseda University
Project Professor, Endowed Research Unit for Nonferrous Metal/Resource Recovery Engineering, the Institute of Industrial Science, the University of Tokyo

Nori Yuki
Executive Officer
Deputy General Manager, Technology Group
JX Nippon Mining & Metals Corporation

Kan Komatsuzaki
Executive Officer in charge of the Administration, Legal, and Public Relations & CSR Departments
General Manager, Administration Department
General Manager, Secretariat
JX Nippon Mining & Metals Corporation

Yuki Narazaki
General Manager, Public Relations & CSR Department
JX Nippon Mining & Metals Corporation

Yuki
For protecting the environment

TOPICS for looking anew at the results through outreach activities.

Projects or leading-edge research, and to provide opportunities for example, it will be important to get them involved in large projects or leading-edge research, and to provide opportunities for looking anew at the results through outreach activities.

TOKORO
It has been an extremely fulfilling experience for me, as I and students from my lab took part in the extension class for high school students and the UniLab events. I feel the students putting on the events also learned a lot. They were highly effective events for human resource development on both sides.

Since we are academics, we all tend to rely on logic to convey things correctly, but when it comes to young people in particular, the newer the age, the greater the need to appeal to intuition. In that sense, having a mascot with an intuitive appeal is extremely important.

The Spread of Industry-Academia Collaboration

Komatsuzaki
What are your views on industry-academia collaboration?

Yuki
Along with the new initiatives, symposiums for professionals are being continued in Phase 2, and the fact that these activities are increasingly gaining momentum is a plus in terms of establishing a firm base for the Endowed Unit.

As for collaboration, in April 2017, right after the start of Phase 2, an endowed class titled “Laboratory of Non-ferrous Extractive Metallurgy” was established by Mitsubishi Materials at Kyoto University. Then in April 2018, a joint research department was created with Sumitomo Metal Mining in the Institute of Multidisciplinary Research for Advanced Materials of Tohoku University.

The problem is, the results of developing the next generation are increasingly gaining momentum is a plus in terms of establishing a firm base for the Endowed Unit. Are there any examples of initiatives that can be continued in Phase 2, and the fact that these activities are increasingly gaining momentum is a plus in terms of establishing a firm base for the Endowed Unit.

The future is now set to be an activity of the industry as a whole. The latter, in addition to heightening basic knowledge of and interest in nonferrous metals through joint research, is creating opportunities for getting in touch with the world of manufacturing through factory tours and seminars. I believe it is important that both the Endowed Unit and endowed classes, each with their own characteristics, energize the nonferrous metals industry and help to secure and develop human resources. The notion of not limiting our efforts to one university and one corporation, which we had when Phase 1 began, is starting to become a reality now, after six years. A framework of collaboration and cooperation with the Mining and Materials Processing Institute of Japan will also become increasingly important going forward.

TOKORO
The fact that the trend of endowed classes is spreading to other universities and corporations is evidence of how the Endowed Unit is putting its message with major impact.

For a long time the university has experienced a “postdoc* problem” among young researchers, and the problem is not limited to this field. With so many researchers wanting to remain in the university but facing a lack of postdoctoral positions, a negative spiral often results in which students decide not to go on to pursue a doctorate because they feel they won’t be able to remain in the university after they complete their studies. I have hopes for industry-academia collaboration as a way of giving these young people a place to be active in the research area and, through outreach activities, an opportunity to grow. It would be good if through industry-academia collaboration, programs could be created from a systematic and long-term perspective to enable young people to carry on research with peace of mind. As academic societies and associations would play a major role in such programs, I would like to ask them also to play coordinating and leadership roles.

* Postdoc: Postdoctoral researcher, a researcher who is appointed to a fixed-term position after earning a doctoral degree.
Roundtable Discussion on Phase 2 of the JX Metals Endowed Unit

At the Tsuruga Plant* of JX Nippon Mining & Metals, commercial feasibility trials on lithium-ion battery recycling have been underway since April 2010. What Are Lithium-Ion Batteries?

Lithium-ion batteries are essential to our daily lives. When people think of lithium-ion batteries, the typical image that comes to mind is batteries in small, portable devices; yet they are also used in electric vehicles including hybrid cars, buses, trucks, and trains, and as backup power sources in aircraft and artificial satellites. An advantage of lithium-ion batteries is their rechargeability. Their high energy density results in large charging capacity despite their compact size. What is more, they can be recharged by repeated topping up.

While these batteries are today used in many different applications, the continued availability of their raw materials is in question. Lithium-ion batteries are made from Lithium along with nickel, cobalt, manganese, and other metals. These are all what are called rare metals, with relatively limited reserves worldwide. They are also difficult to separate as single metals, and costly to recover. Cobalt, in particular, is produced not only in small amounts, but also in limited regions, raising concerns about future availability shortages.

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Development of Lithium-Ion Battery Recycling Technology in the Company

With the aim of developing lithium-ion battery recycling technology, JX Nippon Mining & Metals built a commercial feasibility trial plant in 2010 in Tsuruga, Fukui Prefecture, where we have been carrying out technology development ever since. When the plant first went into operation, testing began on using as a raw material the scrap generated in the process of manufacturing cathode materials (in which rare metals are used), one component of Lithium-ion batteries. Scrap generated in the product manufacturing process at factories or other facilities is called primary scrap, while secondary scrap is from products at the end of their life following use in our daily lives. Compared to primary scrap, secondary scrap requires a more advanced level of recycling technology, since the routes for collection of discarded products are many and varied, and the kinds and percentages of metals contained in the products vary. After carrying out technology development for recycling of primary scrap, we began developing technology for secondary scrap recycling in around 2014, testing the recycling of end-of-life lithium-ion batteries from laptops, cell phones, tablet PCs, and other devices. As a result, in addition to the recovery of nickel and cobalt, we have succeeded for the first time anywhere in recovering lithium, for which recovery was believed particularly difficult, from end-of-life batteries.

For protecting the environment

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**Process of Lithium-Ion Battery Recycling**

To recover the metals cobalt, nickel, and lithium, the end-of-life lithium-ion batteries are first incinerated (roasted) and the battery casing and the organic materials used as electrolyte are removed. Next, crushing and separation are performed, and powder called battery powder is recovered. The battery powder contains cobalt, nickel, lithium, and other metals in concentrated form. The powder is dissolved in acid, resulting in a mixed metal solution. Technology called solvent extraction is used to separate and recover each of the metals mixed together in the solution. Solvent extraction is a separation and recovery technique in which a solution and oil (organic solution) are mixed together, and metal ions in the solution are transferred from the solution into the oil. By using different types of oils and adjusting the pH of the solution, it is possible to transfer only the desired metal from the solution to the oil. It is also possible to return the desired metal from the oil to a solution.

At the Tsuruga Plant, this technology is used to separate and recover each metal from a solution of mixed metals, successfully recovering cobalt, nickel, and lithium.

**Looking Ahead**

Today the world of automotive vehicles is in the midst of major change. In China and Europe, there is a clear trend away from gasoline-powered to electric vehicles, with active entry into the market even by companies that are not traditional automakers. The batteries used in these vehicles are also lithium-ion batteries. Demand for the raw materials used in lithium-ion batteries will grow increasingly, making them harder to obtain.

Drawing on its technological advantages, JX Nippon Mining & Metals will advance lithium-ion battery recycling as a new source of this metal to continue its contributions to realizing a sustainable society.

**VOICE**

For Promoting Technological Progress

Jureichi Arakawa
Coordinator
ART Section
JX Nippon Tsuruga Recycle Co., Ltd.

After engaging in the development of lithium-ion battery recycling technology at the Technology Development Center, I have been involved in the commercial feasibility trial at the Tsuruga Plant since 2012. We configured the process for recycling end-of-life lithium-ion batteries by combining the sales and marketing capacity to collect the raw material, the development capability involved in process improvement, and the shop-floor capacity to operate the plant. I believe each of the people in charge of these various aspects carried out their roles with a sense of responsibility, resulting in a successful outcome. Since the Tsuruga Plant currently uses end-of-life lithium-ion battery scrap as raw material, measures to deal with impurity are essential. As the volume of scrap to be processed grows, the amount of impurity to be removed also increases, so we are constantly under pressure to develop impurity removing technology.

Today, when electric vehicles are becoming more commonplace, I feel that the role of the Tsuruga Plant is spreading beyond Japan to the wider world. By continuing our efforts to promote effective use of resources, we would like to contribute to the sustainable growth of society.