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The Accidents and the Incidents Associated with the Disposal of Chemicals at the University of Tokyo

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This study reviewed the reports of the accidents and the incidents associated with the disposal of chemicals in the University of Tokyo from April 2004 to March 2012 and divided the reports into 6 main categories with 13 subcategories, depending on the situations associated with disposal of chemical wastes. As a result, 78 chemical disposal-associated accident or incident reports were found, which accounted for 23.8% of all the chemical-related accidents and incidents in the university for the 8 years. Among the categories of the process of the disposal of chemicals, the category of the troubles associated with the treatment of chemicals to discard in laboratories had 20 cases, which was the largest in the number of the troubles associated with disposal of chemicals, followed by 12 cases of the category of the troubles associated with the discard of chemical wastes into waste containers or waste cases in laboratories, 11 cases of the category of the troubles during the transports of chemical wastes from laboratories to calling-in points and 10 cases of the category of inadequate discard of chemicals into the sewages in laboratories. As a consequence, 68 cases (87.2%) of the 78 chemical disposal-associated troubles happened in laboratories or during the transport of chemical wastes from laboratories to calling-up points. These results demonstrate the significance of further improvement in the education, the training and the supervising for the members of laboratories regarding the disposal of chemicals.

Keywords: Chemical, Disposal, Waste, Accident, Incident, University, Academic setting

1. Introduction

Adequate treatment of chemical wastes from laboratories is essential matter in universities and other academic institutions. However, the chemical wastes from laboratories of universities and other academic settings include a small amount but a variety of substances. Especially in colleges and universities, a variety of persons form immature students to adept researchers are involved in experiments using chemicals and generation of chemical wastes. That is why the disposal of chemicals in colleges and universities has the possibility to be accompanied with hazardous issues. However, no study can be found regarding accidents or incidents associated with the disposal of chemicals in universities and other academic settings, although not a few reports and studies were reported regarding the accidents associated with waste treatment[1-6].

The procedures of the disposal of chemicals from laboratories include handling of hazardous chemicals used in experiments into stable wastes, discard of used chemicals into containers, storage of chemical wastes in laboratories, transfer of the chemical wastes from laboratories to calling-in points, the transfer of the collected chemical wastes from the calling-in points to facilities for the treatment of chemical wastes, storage of the collected chemical wastes in the waste facilities, carrying out of the collected chemical wastes to chemical waste disposers outside universities and other academic institutions. Additionally, some universities and institutions finally dispose the collected chemical wastes in their waste facilities by themselves. Moreover, the treatment of chemical wastes includes the analysis of unknown chemicals and wastes to make clear what kinds of chemicals are comprised. All of these procedures for the disposal of chemical wastes have risk of accidents.

From April 2004, the University of Tokyo has laid down the reporting of all accidents and incidents associated with research, education and other affairs in the university to the head office. Among the accident and incident reports, not a few chemical disposal-related troubles are included. Based on the data of the reports, this study intends to review these chemical disposal-related accidents and incidents which occurred at the University Tokyo from April 2004 to March 2012 for the purpose of indicating the points to which sufficient attention should be paid in the disposal of chemicals in universities and other academic settings to prevent troubles associated with disposal of chemicals.

2. Methods

2.1 Definition of terms

In this study, “accident” is defined as a trouble with injury or health damage, while “incident” is defined as a trouble without injury or health damage. Additionally, in this study, “disposal of chemicals” is defined to include the process of treatment of chemicals to discard in experiments as well as discard of chemical wastes, storage of chemical wastes, transport of chemical wastes

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and final treatment of chemical wastes.

2.2 The collection of data

At first, the accidents and the incidents associated with chemicals were extracted from the accidents and the incidents reported to the Division of Environment, Safety and Health of the University of Tokyo from April 2004 to March 2012.

Secondary, the chemical waste-disposal troubles were selected among the accidents and the incidents associated with chemicals.

2.3 Categorization of the accidents and the incidents associated with disposal of chemicals

The accidents and the incidents associated with disposal of chemicals were divided into the following 6 main categories with 13 subcategories.

A: The accidents or the incidents during handling of chemicals to discard
- A1: The troubles during treatment of chemicals into stable waste to discard after experiments
- A2: The troubles associated with discard of chemicals into waste containers or waste troubles in laboratories
- A3: The troubles associated with handling of chemicals before final treatment of chemical wastes in the chemical waste-treatment facilities of the university

B: Inadequate disposal of chemical wastes in laboratories
- B1: Inadequate discard of chemical wastes into sewages in laboratories
- B2: Inadequate disposal of chemical wastes in laboratories, excluding discard of chemicals into sewages
- B3: Inadequate disposal of chemical wastes in the chemical waste-treatment facilities of the university

C: The accidents or the incidents during storage of chemical wastes and needless chemical reagents
- C1: The troubles associated with storage of chemical wastes in laboratories
- C2: The troubles associated with storage of needless chemical reagents in laboratories
- C3: The troubles during storage of chemical wastes in the chemical waste-treatment facilities of the university

D: The accidents or the incidents associated with transport of chemical wastes
- D1: The troubles during transport of chemical wastes from laboratories to calling-in points of chemical wastes
- D2: The troubles at the calling-in points of chemical wastes
- D3: The troubles during the transport of chemical wastes from the calling-in points to the chemical waste-treatment facilities of the university
- D4: The troubles during the carrying out of collected chemical wastes from the chemical waste-treatment facilities of the university to chemical waste disposers outside the university

E: The accidents or the incidents in the analysis of components of unknown chemical reagents or unknown chemical wastes in the chemical waste-treatment facilities of the university

F: The accidents or the incidents in the final treatment of chemical wastes in the chemical waste-treatment facilities of the university

2.4 The analysis of the chemical disposal-related accidents and incidents of each category

After the categorization of the reports of chemical disposal-related accidents and incidents, the causes, the situations and the harms of the accidents and the incidents of each category were examined, followed by the consideration of analogies and measures for prevention of reoccurrences in each category.

3. Results

3.1 The number of the chemical waste-related accidents and incidents at the University of Tokyo

During the 8 years from April 2004 to March 2012, a total of 1,705 accidents or incidents were reported to the Division of Environment, Safety and Health of the University of Tokyo. Among the 1,705 accidents or incidents, 1,093 cases occurred within the campuses or the premise of the research institutions of the university, excluding the accidents or the incidents in the research forests, the research farm, the research pasture, the research botanic gardens or the dormitories of the university. Additionally, the 1,093 cases occurred within the siting of the university also exclude the medical service-related accidents or the incidents in the university hospitals or in the university veterinary hospital.

Among the 1,093 cases occurred within the siting of the university, 328 accidents or incidents were associated with chemicals used in experiments, which accounted for 30.0% of the troubles which occurred within the siting of the university for the 8 years. In these chemical-associated accidents and incidents, 78 cases happened associated with disposal of chemicals, which accounted for 23.8% of the chemical-related accidents and the incidents in the University of Tokyo for the 8 years.

Figure 1 shows the transition of the number of the chemical-related troubles and the number of the chemical disposal-related troubles in each school year from 2004 to 2011 (A school year starts in April and finishes in March of next year in Japan).

3.2 The number of the chemical disposal-related accidents and incidents in each category

The number of the accidents and the incidents of each category are shown in Table 1, which demonstrates that Category A1 (the troubles during the handling of hazardous chemicals into stable waste in laboratories) had the largest number of the accidents and the incidents

Table 1 The number of the accidents and the incidents of each category

Category	The explanation of the category	The number of the cases
Category A	Accidents or incidents during handling of chemicals to discard	**32**
Category A1	Troubles associated with treatment of chemicals into stable wastes to discard in laboratories	20
Category A2	Troubles at discard of chemicals into waste containers in laboratories	12
Category A3	Troubles associated with handling of chemicals before final treatment of chemical wastes in the chemical waste-treatment facilities of the university	0
Category B	Accidents or incidents by inadequate disposal of chemicals	**14**
Category B1	Troubles by inadequate discard of chemicals into sewages in laboratories	10
Category B2	Troubles by inadequate disposal of chemicals in laboratories, excluding discard of chemicals into sewages	4
Category B3	Troubles by inadequate disposal of chemicals in the chemical waste-treatment facilities of the university	0
Category C	Accidents or incidents during storage of chemical wastes and needless chemical reagents	**12**
Category C1	Troubles associated with storage of chemical wastes in laboratories	7
Category C2	Troubles associated with storage of needless chemical reagents in laboratories	4
Category C3	Troubles during storage of chemical wastes in the chemical waste-treatment facilities of the university	1
Category D	Accidents or incidents associated with transport of chemical wastes	**13**
Category D1	Troubles during transport of chemical wastes from laboratories to calling-in points of chemical wastes	11
Category D2	Troubles at the calling-in points of chemical wastes	2
Category D3	Troubles during the transport of chemical wastes from the calling-in points to the chemical waste-treatment facilities of the university	0
Category D4	Troubles during the carrying out of collected chemical wastes from the chemical waste-treatment facilities of the university to chemical waste disposers outside the university	0
Category E	Accidents or incidents in the analysis of components of unknown chemical reagents or unknown chemical wastes in the chemical waste-treatment facilities of the university	**6**
Category F	Accidents or incidents in final treatment of chemical wastes in the chemical waste-treatment facilities of the university	**1**

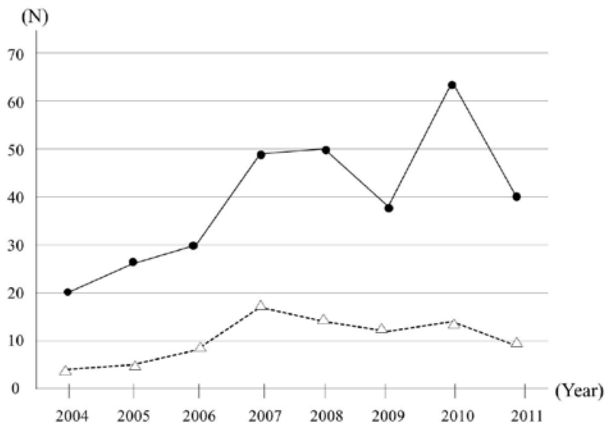

Fig. 1 The number of the accidents and the incidents associated with chemicals and disposal of chemicals in each year from 2004 to 2011 at the University of Tokyo

Black circles (–●–): the number of the accidents and the incidents associated with chemicals.

White triangles (··△··): the number of the accidents and the incidents associated with disposal of chemicals

associated with disposal of chemicals (20 cases), followed by 12 cases of Category A2 (the troubles associated with the discard of chemical wastes into waste containers or waste cases in laboratories), 11 cases of Category D1 (the troubles during the transport of chemical wastes from laboratories to calling-in points), 10 cases of Category B1 (inadequate discard of chemicals into the sewage in laboratories).

In contrast, no accident or incident was reported in Category D3 (the troubles during the transport of chemical wastes from the calling-in points to the chemical waste-treatment facilities of the university) or in Category D4 (the troubles in the carrying out of collected chemical wastes from the chemical waste-treatment facilities of the university to chemical waste disposers outside the university).

3.3 The brief summaries of the accidents and the incidents of each category

3.3.1 Category A

As to the accidents and the incidents during handling of chemicals to discard, 32 troubles were reported, which accounted for the largest proportion (40.5%) of all the accidents and the incidents associated with disposal of chemicals. All cases happened in the laboratories, while no trouble was reported in the chemical waste-treatment facilities of the university.

3.3.1.1 Category A1

Twenty cases were reported as to the accidents or the incidents during handling of hazardous chemicals into stable waste to discard in laboratories, resulting that Category A1 has the largest number of cases in all subcategories and Category E, F as shown in Table 1. The brief summaries of the troubles of Category A1 are demonstrated in Table 2A and 2B.

Ten cases of the 20 accidents or incidents were the troubles with ignition of chemicals and 2 cases were accompanied by explosion or burst during the treatment of hazardous chemicals to discard. The chemicals which induced ignition or burst were metallic potassium (Case A1-1 and Case A1-2), metallic sodium (Case A1-4 and Case A1-5), lithium aluminum hydride (LAH) (Case A1-6 and Case A1-7), n-butyllithium (Case A1-8) and the reaction of dichlorophosphine with hydrogen peroxide (Case A1-9). In addition, there was 1 case that static electricity was presumed to cause ignition in the reaction of sodium chlorite with acetaldehyde (Case A1-10), and in 1 case, heating by heat gun of silica gel contained n-hexane resulted in the ignition of n-hexane (Case A1-11). On the other hand, the case of explosion was induced by discard of a large amount of metallic lithium into water (Case A1-12) and the case of burst was caused by the reaction of metallic potassium with water (Case A1-3).

Four cases of Category A1 were the contact of chemicals with the eyes or the arm of experimenters during treatment of chemicals after experiments (Case A1-13, Case A1-14, Case A1-15 and Case A1-16).

In addition, 4 cases of Category A1 occurred by the disposal treatment of sulfur compounds including thiols, resulting in the aspiration of hazardous gas (Case A1-17) or in the emissions of malodor around the laboratories or the buildings (Case A1-18, Case A1-19 and Case A1-20).

As a result, 5 cases of the 20 cases of Category A were accompanied by injuries or physical discomfort of the experimenters.

3.3.1.2 Category A2

Twelve accidents or incidents were reported associated with discard of chemical wastes into waste containers in laboratories. As a result, Category A2 is the second largest in the number of cases in all subcategories and Category E, F, as shown in Table 1. The brief summaries of the cases of Category A2 are shown in Table 3.

Five cases of the 14 accidents or incidents of category A2 were accompanied by the generation of hazardous gases. The generated gas was chlorine in 3 cases. Two of the 3 cases were caused by the reaction of hydrogen peroxide with chloric acid (Case A2-1 and case A2-2) and the other 1 case was caused by the reaction of concentrated chloric acid with concentrated sulfur acid (Case A2-3). The probable cause of the case with the generation of the gas in Case A2-4 is the generation of hydrogen peroxide gas under alkali condition with sodium hydroxide. The other possibility in Case A2-4 is the generation of chlorine gas by the reaction of hydrogen peroxide with chloroform. On the other hand, the kind of the gas was not identified (Case A2-5).

Two cases of Category A2 were the troubles with the emission of smoke. One of the 2 cases was due to insufficient cooling of the experimental material before discard (Case A2-6), and the other case was presumed

Table 2A The brief summaries of the accidents and the incidents of Category A1 (1)

Case A1-1	**Situation:** After an experiment with metallic potassium in a glove box, a graduate school student brought out the chemical wastes and the equipment from the glove box, resulting in ignition. **Cause:** Insufficient inactivation of the metallic potassium is presumed to lead the reaction of the metallic potassium with the humidity of air. **Result:** The fire was put out by covering a dry fabric cloth, and no one was injured by the ignition.
Case A1-2	**Situation:** A graduate school student forgot to put metallic potassium into toluene after his experiment and brought out the potassium from the fume hood to discard. As a result, the potassium ignited. **Cause:** Lack of inactivation of metallic potassium led to the reaction of the humidity of air, resulting in the ignition. **Result:** The fire was put out by dry sand, but the student got burn injury in his hand.
Case A1-3	**Situation:** An undergraduate student tried to dispose old metallic potassium by dissolving in water. The potassium colored white and looked like completely oxidized. As a result, the beaker was burst and the room was filled with vapor. **Cause:** Misjudgment that the old metallic potassium became inactive led to reaction with water and the burst of the beaker and the emission of fume. **Result:** No one was one was injured and complained health problems by the burst and the emission of the vapor.
Case A1-4	**Situation:** A graduate school student put metallic sodium into ice after the quenching with methyl alcohol to discard, resulting in ignition. **Cause:** The inactivation of metallic sodium with methyl alcohol is presumed to be incomplete, resulting in the ignition by the reaction of metallic sodium with the water of the ice. **Result:** The trousers of the student caught fire, but the fire was put out by extinguishers and the student was rid of burn injury.
Case A1-5	**Situation:** A graduate school student spilled the liquid during the experiment with metallic sodium in a glove box and he wiped the spilled liquid with papers moistened with diethyl ether. Then, he brought the papers out of the glove box and put them into the case filled with acetone to discard. As a result, the case suddenly ignited and the organic solvent around the case caught fire. **Cause:** Insufficient inactivation of metallic sodium before brought out of the glove box resulted in the ignition by the reaction with water or some incompatible chemicals such as halogenous organic solvents. **Result:** The fire was put out by extinguishers and dry sand, but the student got burn injury in his hand.
Case A1-6	**Situation:** In the process of inactivation of lithium aluminum hydride (LAH) with ethyl acetate and diethyl ether to discard, a graduate school student pounded down the aggregated LAH with metallic spatula. As a result, the LAH ignited and the diethyl ether caught fire. **Causes:** The reaction of LAH with the metal of the spatula and the impact on LAH by pounding down with the metallic spatula are presumed to lead ignition. **Result:** The fire was put out by extinguishers and no one was injured by the ignition.
Case A1-7	**Situation:** A graduate school student inactivated old lithium aluminium hydride (LAH) with n-hexane and ethyl acetate to discard in a fume hood. During the treatment, a large amount of gas bubble suddenly occurred and LAH ignited. The fire spread to the organic solvent in the fume hood. **Cause:** Excessive amount of LAH was added and led to the reaction of LAH with ethyl acetate, resulting in the generation of gas bubble and ignition. **Result:** The fire was put out by extinguishers and no one was injured by the ignition.
Case A1-8	**Situation:** After the experiment using a drop funnel to with a small amount of n-butyllithium attached in a closed hood, an undergraduate student tried to wash out the n-butyllithium with acetone, resulting in ignition. The fire was caught by organic solvents in the hood and was extended throughout the hood. **Cause:** Lack of the inactivation of n-butyllithium is presumed to induce the ignition by the reaction of n-butyllithium with air or water during the washing. **Result:** The fire was soon put out by extinguishers, and no one was injured by the ignition.
Case A1-9	**Situation:** A graduate school student treated dichlorophosphine with hydrogen peroxide and ethyl alcohol to discard in a fume hood, resulting in ignition. **Cause:** Excessive reaction of dichlorophosphine with hydrogen peroxide is presumed to happen, which led to the ignition. **Result:** The fire was put out soon by extinguishers, and no one was injured by the ignition.
Case A1-10	**Situation:** A graduate school student inactivated 1% sodium chlorite by slowly injecting 90% acetaldehyde, resulting in ignition. The acetaldehyde caught fire and the fire spread over the table and a book was burned. **Cause:** Static electricity is presumed to react with sodium, which induced the ignition. **Result:** The fire was put out with water, and no one was injured by the ignition.
Case A1-11	**Situation:** After the experiment with column chromatography, an undergraduate student tried to toast the silica gel by a heat gun to remove from the column and discard. As a result, n-hexane which attached to the silica gel ignited by the heat. **Cause:** The use of heat gun to dry up the silica gel which contained n-hexane caused the ignition of n-hexane. **Result:** The fire was soon put out by dry sand, and no one was injured by the ignition.
Case A1-12	**Situation:** A graduate school student discarded 100 g metallic lithium into water at once. As a result, a great amount of hydrogen was generated and caught fire by the reaction fever and exploded. **Cause:** The discard of large amount of metallic lithium into water at once led to hyperactive reaction and the explosion. **Result:** Although the fire was put out by extinguishers, 3 students were injured by the scattered materials.

Table 2B The brief summaries of the accidents and the incidents of Category A1 (2)

Case A1-13	**Situation:** During an assistant professor separated two layers of the waste liquid of phenol, chloroform and isoamyl alcohol by a separating funnel to discard, the separating funnel lost the balance, and the liquid spilled from the funnel over the arm of the assistant professor. **Cause:** The setting of the separating funnel was unstable, resulting in the spill of the chemical fluid. **Result:** The assistant professor was chemically injured on his arm.
Case A1-14	**Situation:** After an experiment with chloroform and methyl alcohol using a separating funnel, an assistant professor tried to wash the funnel with water to discard, but the faucet of the funnel was hard to open, So he left off the protective glasses and he got his face close to the funnel to open the faucet. At the time, the liquid spouted out of the funnel and got into his eye. **Causes:** The pressure in the separating funnel is presumed to be too high, resulting in the difficulty to open the faucet and the spouting of the liquid from the funnel. The experimenter should have decompressed the separating funnel after the experiment. Additionally, The experimenter should have kept wearing the protective glasses when he got his face close to the funnel. **Result:** The medical examination revealed no harm in his eye.
Case A1-15	**Situation:** A researcher collected the residual liquid to discard after the measurement of samples containing tritium and organic solvent without wearing protective glasses. However, the caps of the sample cases were hard to open. When he opened the cap with his strength, the liquid spouted out of the sample case and got into his eye. **Causes:** Mishandling at the opening of the sampling case cap led to the dispersion of the fluid. Additionally, the research did not wear any protective goggles during the treatment of the chemicals. **Result:** The examination in a hospital revealed no harm in the researcher's eye.
Case A1-16	**Situation:** During a filtration of waste liquid after an experiment using potassium hydroxide, the liquid splashed and got into the eye of a graduate school student. **Causes:** The pace of the filtration is presumed to be too high, resulting in the splash of the waste liquid. Additionally, the student did not wear protective goggles at the time, although he wore protective goggles during the experiment. **Result:** The student rapidly washed his eye and went to hospital. Medical examination revealed no harm in his eye.
Case A1-17	**Situation:** A graduate school student treated thiols-attached waste materials with sodium hypochlorite in a fume hood. However, the exhaust ventilation of the fume hood was kept switched off and the student aspirated the gas. **Cause:** The treatment of thiols-attached material without the operation of the fume hood caused the aspiration of the gas of thiols. **Result:** The student complained headache and nausea and got to a hospital, but he became asymptomatic soon after the medical consultation.
Case A1-18	**Situation:** A graduate school student oxidized organic sulfur compound to discard after experiment in a fume hood. However, the scrubber of the fume hood was disabled, resulting in the emission of urban gas-like odor around the building. **Causes:** The maintenance of the scrubber of the fume hood was insufficient, resulting in the emission of malodorous gas of sulfur compound. Additionally, the oxidization to render sulfur compound innoxious might have been insufficient. **Result:** No one complained health problems by the odor.
Case A1-19	**Situation:** A graduate school student filtrated waste liquid containing methanethiol to discard outside a building, resulting in the emission of urban gas-like malodor around the building. **Cause:** Lack of rendering methanethiol innoxious and the treatment of the waste liquid not in a fume hood but outside the building resulted in the emission of malodor. **Result:** No one complained health problems by the odor.
Case A1-20	**Situation:** An undergraduate student washed the experimental vessel with water after the synthesis reaction of thioamide from formamide and phosphorus pentasulfide in a fume hood, resulting in the emission of urban gas-like malodor through the exhaust duct in the building. **Cause:** Lack of rendering innoxious of the synthesized thioamide resulted in the dispersion of malodorous gas of thioamide in the building. **Result:** No one complained health problems by the odor.

Table 3 The brief summaries of the accidents and the incidents of Category A2

Case A2-1	**Situation:** An undergraduate student discarded the liquid with sulfuric acid and hydrogen peroxide in to a waste liquid container of acidic chemicals in a fume hood, resulting in the emission of chlorine gas. Because the fume hood exhausted the chlorine gas, the gas did not spread in the room. **Cause:** The reaction of hydrogen peroxide with hydrogen chloride in the waste liquid container is presumed to generate chlorine gas. **Result:** No one complained health problems by the generated chlorine gas.
Case A2-2	**Situation:** A graduate school student discarded the liquid with sulfuric acid and hydrogen peroxide in to a waste liquid container of acidic chemicals, chlorine gas was emitted and spread in the laboratory. **Cause:** The reaction of hydrogen peroxide with hydrogen chloride in the waste liquid container is presumed to generate chlorine gas. **Result:** The emitted gas was exhausted by the fume hoods and other ventilating devices, and no one complained health problems by the generated chlorine gas.

Case A2-3	**Situation:** An undergraduate student made a mistake to discard aqua regia (75% concentrated chloric acid and 25% concentrated nitric acid) into a waste liquid container for acidic liquid containing concentrated sulfur acid in a fume hood, resulting in the emission of chlorine gas. The student the student aspirated the chlorine gas. **Cause:** The concentrated chloric acid in aqua regia reacted with concentrated sulfur acid, resulting in the rapid generation of chlorine gas. **Result:** The emitted chlorine gas was rapidly absorbed by alkali solution, but the student complained respiratory discomfort due to the aspiration of chlorine gas. After the medical consultation in a hospital, the student completely recovered from the complaint.
Case A2-4	**Situation:** When a professor discarded hydrogen peroxide into a waste liquid of the nucleic-acid extraction reagent containing phenol, chloroform, isopropanol and sodium hydroxide. As a result, a large amount of air bubble was generated and the liquid dispersed. **Causes:** One probable cause is that the gas of hydrogen peroxide was generated under alkali condition with sodium hydroxide. The other possibility is the reaction of hydrogen peroxide with chloroform, which generated chlorine gas. **Result:** A research technician who stood beside the professor was chemically injured on his face by the dispersed liquid.
Case A2-5	**Situation:** An assistant professor discarded the reagents to make histological section (polypropylene glycol diglycidyl ether, 2-dimethyl aminoethanol, 4-vinylcyclohexene dioxide, nonenyl succinic anhydride) into one polyethylene bottle. Approximately 2 hours later, the bottle was melted and brown sticky liquid spilled with smoke. **Cause:** The exact cause of the melt of the bottle is unclear. Some chemical such as 4-vinyl- cyclohexene dioxide might react with polyethylene of the bottle. **Result:** No one complained health problems by the spill of the liquid and smoke.
Case A2-6	**Situation:** A research technician discarded a compound material into a plastic garbage box after an experiment. The compound material was consisted of woods and plastics. In the experiment, the compound material was heated to high temperature, and was discarded after cooling down. A little later after the disposal, the garbage box emitted smoke. **Causes:** The cooling of the compound material was insufficient and the inside of the material remained hot when it was discarded, resulting in smoking in the garbage box. **Result:** The smoke was extinguished with water, and big fire was escaped. No one complained health problems by the smoke.
Case A2-7	**Situation:** Three students discarded needless inorganic reagents into one plastic bag together, resulting in emission of smoke. **Causes:** The cause of the smoke was presumed that hygroscopic reaction by nitride compounds, such as silicon nitride, induced heat generation and the smoke. **Result:** The smoke was extinguished with silica powders, and no one complained health problems by the smoke.
Case A2-8	**Situation:** When a graduate school student brought a tube containing phenol to discard, he spilled the phenol on a leg of another student. **Cause:** The student who brought the tube was not informed of the content of the tube. Insufficient communication of hazardous chemicals i n the laboratory is presumed to induce careless handling during transport of hazardous chemical. **Result:** The student who exposed to the spilled phenol was chemically injured.
Case A2-9	**Situation:** When an associate professor tried to discard a waste liquid of phenol and chloroform, the liquid dropped on his hand. **Causes:** At the discard of the waste liquid, the associate professor paid attention to another matter. Insufficient caution at the discard of hazardous chemical resulted in the drop. Additionally, at the time, the associate professor did not wear any protective gloves. **Result:** The associate professor washed his arm soon, and he had no injury in his arm.
Case A2-10	**Situation:** When a graduate school student was discarding a liquid of trifluoroacetic acid into a waste container, the liquid splashed and attached to his hand. **Cause:** Insufficient caution at the discard of hazardous chemical resulted in the splash. **Result:** The student washed his arm soon, and he had no injury in his arm.
Case A2-11	**Situation:** When a graduate school student transferred organic waste liquid from an old waste liquid container to another new container, he spilled approximately 500 ml waste liquid over the flooring. The waste liquid mainly contained ethyl alcohol, formaldehyde, ammonium picrate and water. **Cause:** The student should have used a hand motion pump to transfer the waste liquid form a waste container to another one, but he tried to transfer directly. Additionally, lack of a tray under the container induced the spread of the spilled liquid. **Result:** The spilled liquid was soon wiped under keeping well-ventilated condition, and no one complained health problems by the spilled liquid.
Case A2-12	**Situation:** When a graduate school student discarded the liquid contained thiols in the scrubber of a fume hood into a waste liquid container, a small amount of liquid was spilled on the flooring, resulting in emission of urban gas-like malodor around the laboratory. **Cause:** Lack of rendering innoxious of thiols before discard resulted in the malodorous emission. **Result:** No one complained health problems by the emission.

that the heat generated by hygroscopic reaction of nitride compounds induced the smoke (Case A2-7). Three cases of Category C were the troubles accompanied by the contact of hazardous chemical wastes with the skin or the eye of experimenters. Three cases of Category C were the troubles accompanied by the contact of hazardous chemical wastes with the skin or the eye of experimenters, phenol and chloroform with the arm (Case A2-9) and trifluoroacetic acid with the hand (Case A2-10).

Additionally, 2 cases of Category A2 were the spill of waste liquid during the transfer or the discard of waste liquid into waste containers (Case A2-11 and Case A2-12).

As a result, 3 cases of the 13 reports were accompanied by injuries or physical discomfort of the experimenters in Category A2.

3.3.1.3 Category A3

No trouble was reported concerning handling of chemicals before final treatment of chemical wastes in the chemical waste-treatment facilities of the university.

3.3.2 Category B

In respect to inadequate disposal of chemicals, 13 troubles were reported. All cases happened in the laboratories, while no trouble was reported in the chemical waste-treatment facilities of the university.

3.3.2.1 Category B1

As to inadequate discard of chemicals into sewages in laboratories, 10 cases were reported as shown in Table 4.

Six of the 10 cases of Category B1 were associated with the discard of acids into sewages. Two of the 5 cases were the discard of strong acids due to misunderstanding of the chemicals as water (Case B1-1: mixed liquid of concentrated chloric acid and concentrated nitric acid, Case B1-2: mixed liquid of concentrated sulfuric acid and hydrogen peroxide), and 1 case was the discard of fluoric acid into the sewage due to careless handling of a waste liquid container (Case B1-3). The other 2 cases of the discard of acids were the effluent of acids due to mishandling (Case B1-4: mixed liquid of concentrated sulfuric acid and hydrogen peroxide, Case B1-5: solution of cupper sulfide). In contrast, the remaining 1 case was the discard of diluted nitric acid into the sewage due to ignorance of the method of the treatment of the wastes (Case B1-6: 2~3% nitric acid).

Case B1-7 was also happened due to ignorance of the treatment of the wastes. The case was the discard of anti-freeze reagent with 50% ethylene glycol into the sewage. On the other hand, Case B1-8 was the discard of silicon oil into the sewage by misunderstanding as water.

The remaining 2 cases were caused by violations of the rule of chemical waste disposal of the university. One of the 2 cases was presumed as the discard of thiols into the sewage, resulting in emission of malodor in the building (Case B1-9), and the other case was discard of xylene into the sewage, resulting in the burst of the sewage pipe and the emission of the vapor of xylene (Case B1-10).

Fortunately, no noted environmental and health harms were found by these inadequate discard of chemicals in to sewages.

3.3.2.2 Category B2

Four cases were reported as to unjust disposal of chemicals in laboratories.

Three cases of this category was the unjust disposal of mercury or mercury-contained equipment. One of the 3 was the disposal of plural heat gauges containing mercury into a non-chemical unburnable garbage box in a building, and the 1 case was the disposal of a reagent bottle of mercury in a garbage collection place. The other case was the disposal of a mercury-containing manometer in a garbage collection place, resulting in the spill of mercury. The University of Tokyo has appointed the date for the collection of mercury-containing wastes and has forbidden the disposal of mercury-related substances on other time. So, these 3 cases of Category B2 violated the rule of the university. Fortunately, in any case, the mercury did not flow out into sewages.

The remaining 1 case of Category B2 was the emission of malodor of sulfur compound by unjust treatment to discard. A graduate school student tried to dispose a small amount of dimethyl sulfide by gasifying on a hotplate in a fume hood, resulting in the emission of urban gas-like malodor in the building by the adverse current through the exhaust duct. Fortunately, no one was harmed by the emission of malodor.

3.3.2.3 Category B3

No trouble was reported concerning inadequate disposal of chemicals in in the chemical waste-treatment facilities of the university.

3.3.3 Category C

With regard to the accidents and the incidents associated during storage of chemical wastes and needless chemical reagents, 11 cases were reported. Ten of the 11 troubles happened in laboratories, in which 7 cases were associated with the storage of chemical wastes in laboratories (Category C1) and 4 cases were caused by needless chemical reagents stored in laboratories (Category C2). On the other hand, 1 case occurred during storage of chemical wastes in the chemical waste-treatment facilities of the university (Category C3).

3.3.3.1 Category C1

Seven accident and incidents were reported associated with the storage of chemical wastes in laboratories, as shown in Table 5. Three of the 7 cases of Category C1 were the emission of hazardous gases from waste liquid containers stored in laboratories. One case was the emission of the vapor of organic solvents (Case C1-1), and 1 case was the emission of nitrogen dioxide gas (Case C1-2). The other 1 case is presumed to be accompanied by the generation of the gas of hydrochloric acid during long time storage of concentrated hydrochloric acid (Case C1-3).

One case of Category C1 was the emission of malodor of thiols contained in wastes and the heating by

Table 4 The brief summaries of the accidents and the incidents of Category B1

Case B1-1	**Situation:** A graduate school student misunderstood approximately 200 ml aqua regia (75% concentrated chloric acid and 25% concentrated nitric acid) in a beaker as water and discarded the liquid into the sewage of the laboratory. **Cause:** Lack of the labeling of the content of the beaker led to the misunderstanding of aqua regia as water, although aqua regia is a very hazardous material. **Result:** Soon after the student found the mistake, the student called the professor, and the professor reported to the sewerage bureau of the Tokyo metropolitan government. The sewerage bureau directed the professor to run a large amount of tap water. After the trouble, the monitor of sewerage of the bureau did not find any abnormal value in the pH of the water in the sewage and the emission of hydrogen sulfide was not detected in the sewer system.
Case B1-2	**Situation:** A graduate school student misunderstood the beaker of the acid solution as pure water and discarded the acid solution into the sewage of the laboratory. The acid solution was consisted of 80 ml concentrated sulfuric acid, 20 ml hydrogen peroxide and 20 ml water. **Cause:** Lack of the labeling of the content of the beaker led to the misunderstanding of sulfuric acid and hydrogen peroxide as water, although these chemicals are very hazardous. **Result:** Soon after the student found the mistake, he ran a large amount of tap water and reported to the Environment safety and Health office of the department. The examination of sewage water from the building revealed no abnormality in the pH of the water in the sewage.
Case B1-3	**Situation:** An assistant professor tried to check whether a waste container for fluoric liquid was empty above the sink. When he laid down the container, approximately 200 ml fluoric acid flowed into the sewage. **Causes:** The empty waste container should have separated from other containers on a routine basis. Additionally, the assistant professor should have checked the container above a tray in anticipation of spill. **Result:** The assistant professor ran a large amount of water and reported the Environment Safety and Health (EHS) office of the department. The EHS office directed to keep running the tap water for 3 hours. The examination after the incident revealed no abnormality in the pH and the concentration of fluoric substance of the water in the sewage from the building.
Case B1-4	**Situation:** When a graduate school student poured pure water into the beaker containing concentrated sulfuric acid and hydrogen peroxide in a sink, the liquid with water overflowed into the sewage of the laboratory. **Cause:** Attention was not kept against overflow during flooding into the beaker containing hazardous chemicals. **Result:** The professor of the student soon reported to the sewerage bureau of the Tokyo metropolitan government and was directed to run a large amount of tap water. Fortunately, the examination of sewage pipe of the building revealed no abnormality in the pH of the water in the sewage.
Case B1-5	**Situation:** A researcher made a mistake to discard the solution of cupper sulfide into the tank for the plating liquid waste after an experiment, although the exhaust bulb of the tank was open. As a result, the discarded solution of cupper sulfide flowed into the sewage. **Causes:** The exhaust bulb of the tank should have been closed when it was opened. Additionally, the researcher should have checked the exhaust bulb before discarding of the waste liquid. **Result:** Soon after the researcher found the effluence of the solution of cupper sulfide, he washed the sewage with a large amount of water, and a large amount of sodium bicarbonate was input into the sewage of the laboratory and the cesspits of the building to neutralized acid. The examination after the trouble revealed no abnormality in the pH of the water in the sewage from the building.
Case B1-6	**Situation:** A graduate school student discarded 2~3% nitric acid into the sewage and washed with the tap water. **Cause:** Insufficient instruction for the student concerning the disposal of waste of acids led to unjust disposal of nitric acid into the sewage. **Result:** The associate professor of the laboratory found the unjust treatment of the waste nitric acid, and reported to the EHS office of the department. The EHS office directed to run a large amount of tap water. The examination of the water in the sewage from the building revealed no abnormality in the pH of the sewage water.
Case B1-7	**Situation:** A graduate school student discarded 14L anti-freeze reagent mainly containing 50% ethylene glycol into the sewage of the laboratory. **Cause:** Insufficient instruction for the student concerning the disposal of waste of anti-freeze reagent led to unjust disposal into the sewage. **Result:** After a while, the student learned the inadequacy of the treatment of the anti-freeze reagent. Although the student reported to the EHS office of the research institute, it was too late after the discard and was beyond control.
Case B1-8	**Situation:** An undergraduate student misunderstood silicone oil in an oil bath as water and discarded 1.8L silicone oil into the sewage. **Cause:** Lack of the information of the content of the oil bath led to unjust discard of silicone oil into the sewage. **Result:** The staff of the laboratory found the unjust discard. The drain pipe was soon closed and the sewage fluid was collected from the sink and the cesspits. After the report to the sewerage bureau of the Tokyo metropolitan government, the examination revealed no abnormality in the oily graduation of the water in the sewage.

Table 4 The brief summaries of the accidents and the incidents of Category B1 *(cont'd)*

Case B1-9	**Situation:** A sulfur-like malodor blanketed the rooms of a building from the sinks. **Cause:** Inadequate discard of sulfuric substance into the sewage was presumed. Despite of inquiry, it could not be clarified who discarded or what was discarded into the sewage. **Result:** No one complained health problems by the odor.
Case B1-10	**Situation:** A researcher discarded xylene into the sewage of the laboratory after experiments to make tissue sections for microscopic examination, resulting in the burst of the drain pipe and the downstairs laboratory was filled with odor of organic solvent. **Cause:** The laboratory disregarded the rule of the university concerning waste treatment which prohibits the discard of hazardous chemicals including xylene into sewages. **Result:** The downstairs laboratory could not be used for 3 days. No one complained health problems by the leaked xylene. All members of the responsible laboratory were given strict order to take the Environmental Safety workshops of the university.

Table 5 The brief summaries of the accidents and the incidents of Category C1

Case C1-1	**Situation:** The smell of organic solvent was suddenly emitted from a waste liquid container stored in a laboratory and the room was filled with the smell. The waste container mainly contained xylene and acetone. **Cause:** Too long storage of the waste liquid in the laboratory is presumed to lead the fullness of the vapor in the container, resulting in the emission of the vapor of organic solvents. **Result:** The container was moved into a fume hood and the air of the laboratory was quickly exhausted. An undergraduate student complained nausea and lost her consciousness. The student was transferred to the university hospital by ambulance and recovered soon after the arrival in the hospital.
Case C1-2	**Situation:** Brown irritating gas was emitted from a waste liquid container for organic chemicals stored in a laboratory. In the liquid of the waste container, ethyl alcohol, nitrate compounds and nitrite compounds were included. **Cause:** The emitted gas was presumed as nitrogen dioxide gas, which was generated as a result of the oxidation reaction by nitrate compounds and nitrite compounds. **Result:** The container was rapidly moved into a fume hood until the generation of the gas ceased and no one complained health problems by the emission of the vapor.
Case C1-3	**Situation:** A graduate school student found an old bottle in a reagent banquette during putting the laboratory in order. When he brought out the bottle to discard, the cap of the bottle was broken and the bottle fell down, resulting in the break of the bottle and the spill of the content with the emission of white smoke. Afterwards, the chemicals were revealed to be concentrated hydrochloric acid containing ammonium citrate. **Causes:** Long time unattended abandonment of the bottle containing hydrochloric acid is presumed to generate the gas of hydrochloric acid. Additionally, the cap of the bottle was deteriorated, resulting in the falling down of the bottle. **Result:** The air of the laboratory was quickly ventilated and no one was harmed by the spill and the emission of the gas.
Case C1-4	**Situation:** A graduate school student sterilized wastes of biological experiments stored in the laboratory by autoclave. One of the wastes contained thiol, resulting in the emission of urban gas-like malodor of thiol by the heating. **Cause:** The wastes were derived from many researchers and students in the laboratory, and the student involved in the incident did not know the details of the chemicals contained in the wastes. Lack of the expression of the contained chemicals in the wastes and lack of separation of hazardous chemicals such as thiol from other wastes caused the trouble. Additionally, the student should have checked the contents of the wastes before the sterilization by autoclave. **Result:** Although the malodor of thiol was emitted around the laboratory. No one complained health problems by the malodor.
Case C1-5	**Situation:** The spill of chromic acid compounds from a waste liquid container for inorganic acids was found. The floor and the metallic plate around the container were decomposed by the spilled liquid. **Cause:** The spill of the waste liquid was presumed to be too long storage of the waste container for inorganic acids in the laboratory, resulting in the breakage of the container. **Result:** No one was harmed by the spill.
Case C1-6	**Situation:** An undergraduate student overturned a waste liquid container for organic chemicals which was left near a door of the laboratory, resulting in the spill of formaldehyde on the floor. **Cause:** The waste liquid container was inadequately located near the door, which could be easily tripped over. **Result:** The spilled liquid was safely treated and no one was harmed by the spill.
Case C1-7	**Situation:** A graduated school student tripped over a bottle containing the waste of organic liquid beside the sink and spilled the contents in the sink. The spilled liquid included acetone, ethyl acetate and pyridine. **Cause:** The waste liquid container was inadequately located beside the sink, which could be easily tripped over and the spilled contents could easily effluent into the sewage. **Result:** Quick treatment for the spilled liquid avoided from effluence into the sewage and no one was harmed by the spill.

autoclave of the wastes resulted in the emission of malodor of thiol (Case C1-4).

Three cases of Category C1 were the spills of chemical waste liquids from waste containers. One of the 3 cases was leakage of chromic acid compounds from a broken waste liquid container caused by too long storage in a laboratory (Case C1-5). The remaining 2 cases of the spills were occurred by the tip of the containers which were inadequately located (Case C1-6 and Case C1-7).

One case of Category C1 was accompanied by health problem of a student due to the aspiration of the emitted gases of organic solvent (Case C1-1), although the other cases were without injury or health problems of any person.

3.3.3.2 Category C2

Four incidents were reported as to the accidents or the incidents during storage of chemical wastes and needless chemical reagents.

Two of the 4 cases of Category C2 were caused by burst of reagent bottles with emission of white irritating gases when the bottles were tried to open during putting the laboratories in order. Afterwards, the reagents were revealed to be silicon tetrachloride, which emitted hydrogen chlorine gas by the reaction of the humidity of air.

One case of the 4 cases of Category C2 was the spill of sulfuric acid from a bottle stored in a cardboard box which was to be disposed. The bottle is presumed to turn over in the cardboard box, resulting in the melt of the cap of the bottle by the concentrated sulfuric acid. The bottle should have been firmly fixed. No one complained health problems by the spill.

The remaining 1 case of Category C2 was a leak of thiol gas from a compressed gas syringe. When putting needless compressed gas syringes in order, a technician opened a bulb of a gas syringe of thiol gas because of misunderstanding that the syringe to be empty. However, a small amount of gas remained in the syringe, resulting in the emission of urban gas-like malodor in the building.

Fortunately, no one was injured or complained health problems by the troubles of Category C2.

3.3.3.3 Category C3

One case was reported as to the incident during the storage of chemical wastes in the chemical waste-treatment facilities of the university.

An iron case containing 800 ml diethyl ether with 1.4 M methyl lithium was burst in the dangerous materials warehouse. The iron case was deteriorated and the pressure of evaporated diethyl ether was presumed to break the case. The case of the chemicals had been stored in a laboratory more than 7 years before it was brought to the chemical waste-treatment facility. Moreover, the case was stored in the hazardous-materials site of the chemical waste-treatment facility for approximately 5 months. Thus, too long storage of the hazardous chemicals in an iron case was presumed to one of the main cause of this trouble.

Fortunately, the case was not accompanied by ignition and no one was injured by the incident.

3.3.4 Category D

In respect to the accidents and the incidents associated with transport of chemical wastes, 13 troubles were reported. Eleven of the 13 cases happened during the transport of chemical wastes from laboratories to calling-in points (Category D1), and 2 of the 13 cases occurred at the calling-in points of chemical wastes (Category D2). In contrast, no trouble was reported during the transport of chemical wastes from the calling-in points to the chemical waste-treatment facilities of the university (Category D3) or during the carrying out of collected chemical wastes from the chemical waste-treatment facilities of the university to chemical waste disposers outside the university (Category D4).

3.3.4.1 Category D1

Eleven cases were reported as to the incidents during the transport of chemical wastes from laboratories to calling-in points.

One of the 11 cases of Category D1 was the spill of mercury from a manometer during the transport from a laboratory to be discarded.

All of the other cases of Category D1 were the falls of waste liquid containers from carriages and spills of waste liquids during the transport from laboratories to calling-in points of chemical wastes. Slops, dumps or obstacles on the routes from the laboratories to the calling-up points were involved in the falling of waste containers in many incidents, Additionally, overloading on carriages, transports by only one person and incomplete close of the caps of the waste liquid containers were one of the causes in many incidents during transport.

Each cases of Category D1 happened outside buildings and no one was injured or complained health problems by the troubles.

3.3.4.2 Category D2

Two cases were reported regarding the troubles at the calling-in points of chemical wastes.

Both cases are the incidents of the spills of mercury at the collection of wastes containing mercury. One case was the spill of mercury from a manometer, and the other case was the spill from an incompletely closed bag containing mercury. In each case, the spilled mercury was avoided from influx into sewage and no one was harmed by the troubles.

3.3.4.3 Category D3

No accident or incident was reported during the transport of chemical wastes from the calling-in points to the chemical waste-treatment facilities of the university.

3.3.4.4 Category D4

No accident or incident was reported during the carrying out of collected chemical wastes from the chemical waste-treatment facilities of the university to chemical waste disposers outside the university.

3.3.5 Category E

Six accidents or incidents were reported associated with the analysis of composition of unknown chemical reagents or unknown chemical wastes in the chemical waste-treatment facilities of the University of Tokyo, as shown in Table 6.

The 3 cases of this category were the bursts of reagent bottles with emission of gases when the bottles were tried to open. Posterior analysis revealed that one of 3 cases was caused by the reaction of silicon tetrachloride with the humidity of the air and emitted gas was hydrogen chlorine gas (Case E1), and the other 2 cases were caused by the gas generation from silicon compounds, although the precise substance name of the silicon compounds was not identified. One probable cause of these troubles is the generation of chlorine gas by the reaction of chloride silicon with the humidity of the air. (Case E2 and Case E3).

The 2 cases of Category E were burning of chemicals during the analysis of the composition. The one of the 2 cases was occurred by the reaction of oxidized chrome with ethyl alcohol (Case E4), and the other case was presumed to happen by the generated fever in the reaction of ferrous oxide with oxygen in the air into ferric oxide (Case E5).

The remaining one case of Category E was exposure of the face of student to chemical during the analysis of composition using ion chromatography. The chemical liquid dispersed from the chromatography chamber and the student got chemical injury on his face. Afterward, the liquid reagent was revealed to be the solution of nickel nitrate (Case E6).

As a result, 2 cases of the 6 cases of Category E were accompanied by chemical injuries of the involved persons.

3.3.6 Category F

One incident was reported associated with the final treatment of chemical wastes in the chemical waste-treatment facilities of the university. This incident was occurred by a mistake in the handling of the valves of the tubes from a ferrite reaction tank. A freshly recruited technician made a mistake to open an incorrect valve during ferrite reaction for the final treatment of inorganic wastes, resulting in the unexpected spouting of heated water. Fortunately, no one was injured by the incident and the ferrite reaction system was not seriously damaged.

4. Discussion

Up to today, no study can be found regarding accidents or incidents associated with the disposal of chemicals in universities and other academic settings. With this respect, this study is the first which has organized the reports regarding the chemical disposal-associated accidents and incidents with the analysis by categorizing into the groups, that is, handling of chemicals to discard, inadequate disposal of chemicals, storage of chemical wastes, transport of chemical wastes and final treatment of chemical wastes.

As a result, it was revealed that 78 chemical disposal-associated accidents and incidents were reported at the University of Tokyo for 8 years, which accounted for 23.8% of the chemical-related accidents and the incidents that happened from April 2004 to March 2012 in the University of Tokyo. This result indicates that the process of disposal of chemicals cannot be disregarded for the improvement in safety and health management in universities and other academic institutions.

Especially, 68 cases (87.2%) of the 78 chemical disposal-associated accidents and incidents happened in laboratories or during the transport of chemical wastes from laboratories to calling-up points. This result demonstrates the significance of the education, the training and the supervising regarding the disposal of chemicals for the members of laboratories.

In the University of Tokyo, the workshops for environmental safety have been presented for the students and the staffs of the university more than 15 times in a year. Every year, approximately 2,000 students and staffs of the university attend the workshops. In the workshops, the rules concerning the classification of chemical wastes and the treatment of chemical wastes are lectured. Additionally, safety handling of hazardous chemicals and chemical wastes is also one of the main contents of the lecture. The University of Tokyo prescribes that all chemical wastes must be brought forward the chemical waste- treatment facilities of the university. Moreover, for taking out of chemical wastes to the chemical waste-treatment facilities of the university, the rule of the university obligates the attendance at the workshops and passing the examination at the end of the workshops. From this viewpoint, the workshops for environmental safety have a significant role for keeping safety in the treatment of chemical wastes in the university.

However, not a small number of accidents and incidents associated with disposal of chemicals in the laboratories of the university indicate the necessity of the reinforcement and the upgrading of education and training, including the workshops for environmental safety, for promoting safety in disposal of chemicals. To prevent reoccurrence of these troubles, the awareness of the members including students, staffs and researchers in the university has to be uplifted that accidents and incidents may happen in every situation associated with disposal of chemicals. The uplift of such awareness of the members in the university will enhance the prudence in the handling of chemicals to discard and in the treatment of chemical wastes. Therefore, the measures for the effective enhancement of the awareness of the members in the university will be indispensable in the reinforcement and the upgrading of education and training for the safety in chemical disposal. When think on the measures concerning the safety education and the safety training, it should be taken into consideration in which situations accidents and incidents often happen associated with chemical disposal. Additionally, providing the members of the university with the

Table 6 The brief summaries of the accidents and the incidents of Category E

Case E-1	**Situation:** When a research technician opened a bottle of unknown reagent for the analysis of the composition outside the fume hood, the reagent bottle burst with the emission of white irritating smoke. The technician was exposed to the chemical on his face. Afterward, the reagent was revealed to be silicon tetrachloride. **Causes:** The reaction of silicon tetrachloride with the humidity of the air generated chlorine gas, which burst the reagent bottle by the pressure of the gas. Additionally, the bottle should have been opened in a fume hood with the shield against burst and explosion. **Result:** The air of the analytical laboratory was quickly ventilated. The technician had a slight chemical injury on his face.
Case E-2	**Situation:** When a research technician and an undergraduate student opened a bottle of unknown reagent for the analysis of the composition outside the fume hood, the bottle burst and the liquid adhered to the face of the student. Afterward, the reagent was revealed to be silicon compound. **Causes:** The reaction of silicon compound with the air generated gas, resulting in the burst of the reagent bottle. Although the precise substance name was not identified, one probability is the generation of chlorine gas by the reaction of chloride silicon with the humidity of the air. Additionally, the bottle should have been opened in a fume hood with the shield against burst and explosion. **Result:** The student quickly washed his face with the tap water and no chemical injury was found on his face in the examination in hospital.
Case E-3	**Situation:** When a research technician opened a bottle of unknown reagent for the analysis of the composition in the fume hood, the bottle burst with the emission of white smoke. Afterward, the reagent was revealed to be silicon compound. **Cause:** The reaction of silicon compound with the air generated gas, resulting in the burst of the reagent bottle. Although the precise substance name was not identified, one probability is the generation of chlorine gas by the reaction of chloride silicon with the humidity of the air. **Result:** The emitted gas was exhausted from the fume hood, and no one was injured or complained health problems by the burst and the emission of the gas.
Case E-4	**Situation:** During an undergraduate student analyzed an unknown liquid reagent by ion chromatography, the syringe and the filter of the chromatography chamber was suddenly departed and the student was exposed to the dispersed liquid on his face. Afterward, the liquid reagent was revealed to be the solution of nickel nitrate. **Causes:** The pressure inside the chromatography chamber is presumed to be very high, resulting in getting out of joint between the syringe and the filter and the dispersion of the liquid. Additionally, the connection of the syringe with the filter might be insufficiently closed. **Result:** Although the student quickly washed his face, he had a slight chemical injury on his face.
Case E-5	**Situation:** When an undergraduate student put a sample of an unknown waste liquid on a Mylar film and tried to start the X-ray fluorescent analysis, the sample suddenly generated heat and the film was burned. After the heat was cooled off, the sample was discolored into brown. The analysis revealed the sample was ferrous oxide. **Cause:** The heat is presumed to be generated by the fever of the reaction of ferrous oxide with oxygen into ferric oxide. **Result:** No one was injured by the burning.
Case E-6	**Situation:** During the analysis of the composition of an unknown liquid, a small amount of the liquid spilled over the table. So, a research technician wiped the spilled liquid by a paper with ethyl alcohol, resulting in ignition of the paper. Afterward, the liquid was revealed to be chromium trioxide. **Cause:** The ignition was induced by oxidation reaction of chromium trioxide with alcohol. **Result:** The fire was soon extinguished by an extinguisher. and no one was injured by the ignition.

information of case examples of the accidents and the incidents associated with chemical disposal in a variety of situations will be one of the effective measures in the education and the training. In this meaning, the results of this study will contribute to the consideration of improvement in education and training for the safety in chemical disposal.

With regard to the chemical disposal-associated accidents and incidents in laboratories, Category regarding the handling of chemicals to discard (Category A) had the largest number of troubles. Especially, 21 cases were found in the accidents and the incidents during treatment of chemicals into stable waste to discard after experiments in laboratories (Category A1), which accounted for the largest proportion in all categories and subcategories.

Category A1 includes 9 cases of ignition of chemicals. The chemicals which caused the ignition were metallic potassium in 3 cases, LAH in 2 cases and metallic sodium in 1 case. Additionally, 1 case of the explosion was caused by metallic lithium discarded into water. The other 2 cases were the ignition during the reaction of dichlorophosphine with hydrogen peroxide and during the reaction of sodium chlorite with acetaldehyde.

The danger of the reaction of metallic potassium and metallic sodium with water is generally known, and metallic potassium can ignite with the reaction of humidity of air[7,8]. The students who use alkali metals are lectured concerning the danger of the reaction with water in the environmental safety workshops and in their department or the majors before the treatment of alkali metals, including the methods for the inactivation of these chemicals after experiments. However, insufficient inactivation of alkali metals after experiments was presumed to be the main causes of the ignition of the chemicals. These accidents and incidents indicate the necessity of enforcement of further safety education, training and supervising for the treatment of alkali metals during and after experiments. Additionally, attention of the students involved in the troubles might become inadequate in the process of picking up after the experiments or in the process of treatment of discarding reagents, although they had paid suited attention to the treatment of the alkali metals during experiments.

As to LAH, the danger of LAH is well described in technical books, in which the friction for the lump of LAH is strictly warned[9]. In the one case, the student pounded down the aggregate LAH with metallic spatula, which can be said as reckless action. Insufficient education, inadequate supervision and lack of knowledge are supposed to lead to the incident.

In Category A1, the case accompanied by the explosion was induced by reaction of 100 g metallic lithium with water. This explosion injured 3 students, which is one of the critically serious accidents in the University of Tokyo. This accident was complete deviance from general procedure for the disposal of metallic lithium. Technical books describe that metallic lithium should be disposed by the treatment with 95% ethyl alcohol[10,11], and this accident was supposed to be caused by lack of knowledge as well as insufficient education and inadequate supervision for the disposal of metallic lithium.

In addition, 4 cases in Category A1 caused the emission of urban-gas-like malodor by the inadequate disposal of thiols and other sulfur compounds. Thiols and some sulfur compounds are notable as malodorous chemicals[12,13], which require to be rendered innoxious by oxidation or other methods before disposal[14]. In the 2 cases of the 4 troubles, the emission of malodor happened during oxidization to render the chemicals innoxious in fume hoods, but the fume hood did not operate during the treatment in 1 case and the scrubber of the fume hood did not function during the treatment in the other case. These 2 cases demonstrate the importance of making sure but for treatment the chemicals for disposal. In contrast, the other 2 cases with the emission of malodor, the thiols were not rendered innoxious in the treatment for disposal. These 2 cases will be attributed to the lack of hazard perception and the ignorance of the methods for proper treatment at the disposal of malodorous chemicals. More sufficient instruction and supervising concerning will be required to prevent such troubles associated with deficient hazard perception and ignorance of the methods for proper treatment of hazardous chemicals to discard including malodorous substances.

When the cases of Category A1 are reviewed, the following matters are supposed to be required to prevent the accidents and the incidents in treatment of chemicals to discard after experiments in laboratories. At first, experimenters should pay sufficient attention in the treatment of hazardous chemicals to discard as well as during proceeding experiments. Wearing protective equipment such as protective goggles and protective gloves is also essential in the process of the treatment of chemicals to discard, and proper use of fume hoods is required in the treatment of hazardous chemicals to discard in the same manner. Second, the adequate instruction concerning safety handling of chemicals should be given to students and staffs not only for proceeding experiments but for treatment of chemicals to discard after experiments, because some cases were found in Category A1 which was attributed to lack of proper knowledge regarding the methods for treatment of hazardous chemicals to discard.

In Category A2, 13 cases were reported, which were associated with the discard of chemical wastes into waste containers in laboratories. These cases include 4 cases with the generation of hazardous gases, 4 cases with the exposure of eye or skin to hazardous chemicals, 2 cases with the emission of smoke, 2 cases with the spill of waste liquids and 1 case with bumping reaction

Five cases of the 13 troubles of Category A2 were caused by incompatible reactions. These cases demonstrate the necessity of well-marked expression of chemical contents in waste containers and the significance of sufficient attention at the discard of chemicals into waste containers not to induce incompatible reactions with substances contained in containers. Especially, 3 cases of the 5 troubles with incompatible reactions of Category A2 were occurred by the reactions of hydrogen peroxide with other chemicals. Hydrogen peroxide is a powerful oxidant, which is well known to react hazardously with a variety of chemicals[15,16], which requires more cautious treatment at the discard of this chemical.

Additionally, 4 cases found in Category A2 which were accompanied by the exposure of eye or skin to waste chemicals. These cases indicate the requirement of more prudent handling and wearing of protective equipment including goggles and gloves at the discard of chemicals.

In the review of the troubles in Category A2, the following matters are supposed to be required to prevent the accidents and the incidents at the discard of chemicals into waste containers. Firstly, who discard chemical wastes into waste containers should confirm the contents in the waste containers, not to induce incompatible reactions. In this process, experimenters have to know incompatible chemicals with the chemicals they discard, using Safety data Sheets (SDSs) and other information sources. Additionally, the well-marked expression of the chemicals contained in waste containers will contribute to avoid the occurrence of incompatible reactions after discard of chemical wastes. Second, experimenters should prudently treat the chemical wastes at the discard and they have to wear protective equipment such as goggles and gloves at the discard of chemical wastes as well as during experiments.

As to the accidents or the incidents by inadequate disposal of chemicals (Category B), 14 cases were found, in which 10 troubles were inadequate discard of chemicals into sewage in laboratories (Category B1) and 4 troubles were inadequate disposal of chemicals in laboratories excluding discard of chemicals into sewages (Category B2)

The 10 cases of Category B1 show that not a few troubles with inadequate discard of chemicals into sewage in laboratories have occurred in the University of Tokyo, although disposal of hazardous chemicals in to sewage is forbidden by the rules of the university abided by the Sewage Law and the Water Pollution Prevention Law of Japan which prohibited people from discarding various environmentally hazardous chemicals. Additionally, the prohibition has been firmly informed in the environmental safety workshops and by repeated warnings from the Division of Environment, Health and Safety in the headquarters of the university.

The chemicals inadequately discarded into sewage included 6 cases of acids, 1 case of ethylene glycol, 1 case of silicon oil, 1 case of thiols and 1 case of xylene, and the reasons of inadequate discard of chemicals into sewage were due to misunderstanding as water in 3 cases, careless handling or mishandling of waste liquids in 3 cases, ignorance of the method of treatment of waste liquids in 2 cases and intentional violation in 2 cases. Well-marked expression of the chemicals contained in waste containers and cases will contribute to the prevention of misunderstanding of the chemicals contained in containers and cases, which sometimes leads to discard of hazardous chemicals into sewage. Furthermore, the reinforcement of instruction concerning the methods of treatment at disposal of hazardous chemicals will be required to prevent discard of prohibited chemicals into sewage by ignorance and intentional violation.

In the 4 cases of Category B2, 3 cases were unjust disposal of mercury or mercury-contained equipment. The University of Tokyo has assigned the date for the collection of mercury-related wastes 4 times a year, and the rule of the university has prohibited from discarding mercury-related wastes in the other days. In this respect, these 3 cases of mercury-related unjust disposal completely disregarded the measures and the rules for environmental management of the university. To prevent such violating behaviors, tireless efforts will be indispensable to uplift the recognition of staffs and students in the university that everyone in the university have to always observe the measures and the policies for environmental management of the university.

With regard to the troubles associated with storage of chemical wastes in laboratories (Category C1), 6 troubles were reported for the 8 years. Four of the 5 cases of Category C1 were occurred by too long storage of waste liquid containers in the laboratories or the bottle containing chemical waste liquid, in which 3 cases were the troubles with the emission of hazardous gases from the waste liquid containers, and 1 case was the spill of chromic acids from the broken waste containers. The other 2 troubles of Category C1 were caused by tripping over the waste containers, resulting in the spill of the waste liquid. Inadequate setting of the waste containers attributed to the incidents.

The troubles of Category C1 demonstrate the following matters concerning storage of waste containers in laboratories. At first, the danger of long storage of chemical waste in laboratories is demonstrated. In the University of Tokyo, the waste containers at calling-up points are collected and transported to the chemical waste-treatment facilities every week for all departments, schools and institutes. More positive announcement for the prevention of long storage of chemical waste containers in laboratories will be required. Second, inadequate setting of waste containers should be refrained to prevent the spill of the contents of the containers by tripping over. Additionally, trays should be set under waste containers against spill.

In Category C2, 4 troubles were reported associated with the storage of needless chemical reagents in laboratories. Two of the 4 cases of Category C2 were caused by the reaction of silicon tetrachloride with humidity of the air, resulting in the burst of the reagent bottles with the emission of chlorine gas. In both cases, the reagent bottles of silicon tetrachloride were left as unknown reagents, which were strongly related to the occurrence of the incidents. The other 1 case of Category C2 was the spill of concentrated sulfur acid from a needless reagent bottle, which is supposed to be caused by insufficient fixation of the needless reagent bottle containing hazardous chemical, resulting in turning over and break of the bottle. The remaining 1 case of Category C2 was the leakage of thiol gas from a compressed gas syringe, which was caused by misunderstanding that the gas syringe was empty.

The review of the troubles of Category C2 indicates the following matters concerning storage of needless chemicals in laboratories. At first, needless chemical reagents, especially hazardous chemical reagents including silicon tetrachloride, should not be stored for long time in laboratories. Long time storage of needless chemical reagents in laboratories has the risk to make unknown chemicals. As to silicon tetrachloride, it is known as this chemical is very hazardous, which easily reacts with water and generates hydrogen chloride gas[17,18]. Second, the needless chemicals should be stored with firmly fixed as well as the chemical reagents under use to prevent the break of the reagent bottles. Thirdly, compressed gas syringes should be stored under separation of empty syringes from not empty ones. Additionally, well-marked expression for empty compressed gas syringes will prevent the trouble of gas leakage by misunderstanding.

As to the troubles during the transport of chemical wastes from laboratories to calling-in points (Category

D1), 11 troubles were found and 10 cases of the 11 incidents were falling of waste liquid containers from carriages and the spill of the waste liquids. In not a few cases, slopes, steps or obstacles between laboratories and calling-up points were direct causes of the falling of waste liquid containers. However, overloading of containers on carriages was also involved in these troubles. To prevent the troubles during the transport of chemical wastes from laboratories to calling-in points, refraining from overloading and transport by plural persons will be required. Additionally, the use of the carriage with stockades as shown in Fig. 2 will be effective to prevent the falling of waste containers during transport.

Fig. 2 The carriage with stockades

Finally, 6 troubles of Category E (the accidents and the incidents in the analysis of components of unknown reagents or unknown chemical wastes in the chemical waste-treatment facilities of the university) were reported for the 8 years. Three cases of the troubles were the burst of the unknown chemical reagent bottles, which were revealed to be caused by the reaction of silicon tetrachloride or thiol compounds with the humidity of the air with generation of chlorine gas. Including the 2 incidents of Category C2 which were accompanied by the burst of the bottles containing silicon tetrachloride, these troubles show the danger of silicon tetrachloride and some sulfur compounds, indicating the necessity of prudence in the treatment of these chemicals. In addition, Category E includes 2 cases of heat generation or ignition in the analysis of the composition of unknown chemicals.

The cases of Category E demonstrate the difficulty in the treatment of unknown chemicals. Further prudence will be required in the treatment for the analysis of unknown chemical reagents and unknown chemical wastes. Additionally, laboratories should make efforts not to make unknown chemical reagents or unknown chemical wastes.

In contrast, except for the accidents and incidents during the analysis of the composition of unknown reagents and unknown wastes (Category E), only 2 troubles have been reported for 8 years from the process of collecting chemical wastes at calling-up points to the process of final treatment in the chemical waste-treatment facilities of the university or the process of the carrying out of the collected chemical wastes to chemical waste disposers outside the university. The chemical waste-treatment facilities always keeps a large amount of various hazardous chemicals. In this meaning, the small number of troubles in the chemical waste-treatment facilities, except for the troubles during the analysis of the composition of unknown chemicals, may be due to sophisticated system of the treatment of chemical waste of the facilities as well as skillfulness and sufficient education and training in the staffs.

5. Conclusion

In this study, the accidents and the incidents associated with disposal of chemicals were revealed to account for 23.8% of all troubles associated with chemicals in the University of Tokyo from 2004 to 2011. This result indicates that keeping safety in disposal of chemicals is one of the significant issues in the safety management of the university. Furthermore, this study demonstrated accidents and incidents associated with disposal of chemicals can happen in a variety of situations in the University of Tokyo. Especially, troubles associated with the treatment of chemicals to discard and discard of chemical wastes into waste containers were shown to have a large number of the accidents and the incidents in all categories of chemical disposal. In addition, a number of troubles happen associated with discard of chemicals into sewages and during transport of chemical wastes from laboratories to calling-in points of chemical wastes. Furthermore, this study demonstrated that not a few accidents and incidents took place in the analysis of components of unknown chemical reagents or unknown chemical wastes, during storage of chemical wastes in laboratories and during storage of needless chemical reagents in laboratories.

Not a small number of accidents and incidents associated with disposal of chemicals happened in the laboratories of the University of Tokyo demonstrate the requirement to enhance the awareness of the members who use chemicals in the university for the safety in disposal of chemicals. In this meaning, the reinforcement and the upgrading of education and training, including the workshops for environmental safety, will be required for promoting safety in disposal of chemicals. The results of this study will provide us with available information in the consideration of further improvement in education and training for the safety in chemical disposal.

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