

## Original Research Article

# Knowledge and awareness of ketoacidosis associated with high exposure to acetone-containing products: A cross-sectional assessment

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## Abstract

**Purpose:** To assess the knowledge and awareness of the Jordanian public about the hazards associated with high levels of exposure to acetone-containing products.

**Methods:** The study was conducted between September 2019 and December 2020. An electronic anonymous questionnaire was distributed via different channels to be self-completed by the study population. Socio-demographic characteristics, knowledge about acetone-containing nail polish removers and sterilizing products, and awareness about the risk of ketoacidosis associated with high degree of exposure to these products, were assessed.

**Results:** The findings revealed that a majority of participants were aware of the presence of acetone in nail polish removers (92.61 %) and sterilizing products (84.41 %), regardless of gender, age, educational type and educational level. In addition, females (70.4 or 83.0 %), youngest age group (70.7 or 83.0 %), those with health-related education (56.6 or 76.0 %), and graduates (72.0 or 83.9 %) were significantly ( $p < 0.05$ ) more aware about the safety of these products if inhaled or exposed to flame sources, respectively, than their peers. Moreover, concerning the risks of developing ketoacidosis and raised liver ketone levels as hazards associated with the high degree of exposure to acetone-containing products, females (44.2, 41.9 and 50.6 %), those with health-related education (64.1, 63.4 and 73.3 %), youngest age group (47.4, 44.6 and 56.5 %), and graduates (45.3, 43.5 and 52.8 %), respectively, were significantly more aware than the others ( $p < 0.05$ ).

**Conclusion:** These findings indicate signs of significantly poor awareness about the serious risks associated with acetone-caused ketoacidosis among the study population. Therefore, well-organized educational campaigns are needed to enlighten graduates with health-related education and to improve public perception of the health hazards associated with human exposure to acetone-containing products.

**Keywords:** Acetone, Nail polish removers, Acute toxicity, Ketoacidosis

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## INTRODUCTION

Many household and personal care products contain hazardous bioactive ingredients that may seriously affect not only human health but also the surrounding environment [1]. During the COVID-19 pandemic, varied toxicity cases were caused by exposure to different commonly available chemicals and detergents [2]. Acetone is one of these chemicals that are available in homes and are widely used as nail polish remover [3].

Globally, toxicity caused by acetone and acetone-based products has been reported in a limited number of toxicity cases [4]. The United States Department of Labor published a report about occupational safety and health administration titled "Health hazards in nail salons" which released data on acetone toxicity cases showing that it was mostly related and limited to cosmetic centers [5]. However, there are insufficient records related to the knowledge and attitudes of the public users of these products locally or globally.

Chemically, acetone is a flammable organic solvent that is extensively synthesized and utilized in research and industrial laboratories [6]. The acute toxicity profiles of acetone and acetone-containing products either after short- or long-term exposures, have been reported [7]. Most reported cases of acetone-caused acute toxicity resulted from ingestion or inhalation [8]. Topical use of nail polish remover containing acetone has limited implications in acute acetone toxicity, as there is little acetone absorption through the skin. However, swallowing acetone-containing nail polish remover solution by accident has been shown to contribute to many cases of poisoning [9].

In most cases of acetone-caused toxicity, treatment is primarily based on decontamination and use of the proper medication [10]. This step is considered an important diagnostic and treatment option in most acute toxicities. Anti-anxiety medication in the form of benzodiazepines, tricyclic antidepressants, and selective serotonin reuptake inhibitors (SSRIs) have been helpful in managing the symptoms of neurological toxicity [11].

Acetone toxicity results from production of toxic metabolites known as ketones. High levels of ketones exceed the capacity of the liver to detoxify the poison properly, resulting in ketone toxicity (ketosis) [10]. This is different from the harmful state of ketoacidosis caused by uncontrolled type 1 diabetes, or the nutritional

type caused by ketogenic diets [9]. The clinical manifestations of ketoacidosis may range from mild symptoms such as headache, lethargy, and slurred speech, to lack of coordination and sweet taste in the mouth. Severe cases present with shock and multi-organ failure, electrolyte disturbances, and dangerous arrhythmias [9,12].

A review of extant literature revealed that regional studies focused mainly on methanol as toxic solvent [13], with few publications concerning other toxic organic solvents. Contrary to the public opinion that acetone is a safe substance, it is necessary to develop safeguards for the public concerning acetone-containing products, and health-risk commonly associated with its use [4,7,11]. To the best of our knowledge, this is the first study of its kind in the Middle East in general and in Jordan in particular, on evaluation of public knowledge and awareness regarding the hazards of high degree of exposure to acetone as ingredient in nail polish removers and sterilizing products.

## METHODS

### Sample size

The sample size used in this study was calculated online using an online sample calculator (Raosoft). Based on the statistical data and official figures released by the Department of Statistics of Hashimate Kingdom of Jordan titled: *Population and Family Health Survey (2017-2018)*, the population of the country is about 10,459,865. Therefore, 400 participants were needed to obtain a 95 % confidence interval and a 5 % margin of error. After exclusion of incomplete and contradictory responses, the final data included 1001 participants.

### Study instrument

A cross-sectional survey study was conducted during the period from September 2019 to December 2023. An electronic anonymous questionnaire was designed and distributed to the public comprising citizens living in all cities of Jordan, through social media platforms; Facebook, WhatsApp messages, personal messages, and emails. All questions were self-completed by the participants.

### Questionnaire survey

The questionnaire was designed and written in English and Arabic languages, based on published literature, and was distributed to the public using an online survey portal and Google forms. The final version of the questionnaire was

double-checked by another two peer-review experts in the field, so as to ensure high quality and clarity of the questionnaire items. The questionnaire consisted of three sections, each with different features viz: section I: socio-demographic characteristics, i.e., gender of participant, age, and level and type of education; section II: knowledge-related items, i.e., assessment of information on acetone-containing nail lacquer removers and sterilizing agents; and section III: awareness about safety and health risks associated with exposure to acetone-containing products, with focus on understanding of ketoacidosis as mechanism of acetone toxicity.

### Ethical approval and patient consent

Informed consent form was included at the beginning of the survey in form of the question: *Do you want to participate in this survey?* and the statement: *It is voluntary, and not obligatory to participate; you are free to withdraw at any time you want.* The study objectives and their importance were described and explained to participants through written information in the survey. This study was conducted in accordance with the Declaration of Helsinki [14]. Institutional approval was obtained from the Institutional Review Board (IRB) at Yarmouk University (approval no. der/2024/360).

### Statistical analysis

The responses were analyzed using Statistical Package for Social Sciences (SPSS; IBM Corp., Armonk, NY, USA) version 22.0 and Excel program. Data were tabulated as percentages and frequencies for descriptive statistics. The possible relationships among different variables were assessed using Chi-square test. Differences were assumed to be significant at  $p < 0.05$ .

## RESULTS

### Socio-demographic characteristics

A total of 1001 participants with valid responses were involved in the final analysis. The number of female participants ( $n = 761$ ) was about threefold the population of male participants ( $n = 240$ ; 76 % vs. 24 %). The socio-demographic

characteristics of the study population are shown in Table 1.

**Table 1:** Demographic characteristics of study population ( $n = 1001$ )

Characteristic	n (%)
<b>Gender</b>	
Male	240 (24.0)
Female	761 (76.0)
<b>Age (years)</b>	
18-25	616 (61.5)
26-35	203 (20.3)
≥ 36	182 (18.2)
<b>Educational level</b>	
Illiterate	18 (1.8)
≤ Secondary	169 (16.9)
Diploma or Bachelors	751 (75.0)
Postgraduate	63 (6.3)
<b>Educational type</b>	
Health-related	513(51.2)
Not health-related	488 (48.8)

### Participants' knowledge of acetone-containing nail lacquer removers and sterilizing products

The knowledge of the participants regarding acetone-containing nail lacquer removers and sterilizing products is shown in Table 2. The findings revealed that majority of the participants were aware of the presence of acetone in nail polish removers (92.61 %) and sterilizing products (85.41 %). However, only a few of the participants were aware that acetone-free nail lacquer remover is commercially available. A cross-tabulation analysis was performed to assess differences in knowledge level regarding the presence of acetone in nail lacquer removers or sterilizing products as per participants' demographic characteristics. Table 3 and Table 4 show that participants were significantly highly knowledgeable about the presence of acetone in these products, regardless of gender, age, educational type and educational level ( $p < 0.05$ ).

Assessment of knowledge level regarding the presence of acetone-free nail lacquer removers, based on demographic characteristics such as participants' gender, age, educational type and educational level, revealed significant ( $p < 0.05$ ) poor knowledge among all the subjects. These data are shown in Table 5.

**Table 2:** Knowledge about acetone-containing nail lacquer removers and sterilizing products ( $n=1001$ )

Questions for positive knowledge	Frequency (yes); n (%)
Do Nail lacquer removers contain acetone?	927 (92.61)
Is Acetone available in sterilizing products?	855 (85.41)
Is there an acetone-free nail lacquer remover?	250 (24.98)

**Table 3:** Knowledge about the presence of acetone in nail lacquer removers in relation to demographic characteristics (n = 1001)

Characteristic		Frequency (yes); n (%) <sup>*</sup>	*P-value
Gender	Male	203 (84.6)	0.000
	Female	724 (95.1)	
Age (years)	18 – 25	585 (95.0)	0.000
	26 – 35	175 (86.2)	
	≥ 36	167 (91.8)	
Educational type	Health-related	499 (97.3)	0.000
	Non-Health-related	428 (87.7)	
Educational level	≤ high school	153 (82.2)	0.000
	≥ Graduate	774 (95.1)	

**Note:** \*P-values and percentages were calculated based on the number of participants indicated in Table 1

**Table 4:** Knowledge about the presence of acetone in the sterilizing products in relation to demographic characteristics (n = 1001)

Characteristic		Frequency (yes) n (%) <sup>*</sup>	*P-value
Gender	Male	150 (62.5)	0.003
	Female	555 (72.9)	
Age (years)	18 – 25	471 (76.5)	0.000
	26 – 35	120 (59.1)	
	≥ 36	114 (62.6)	
Educational type	Health-related	410 (79.9)	0.000
	Non-health-related	295 (60.5)	
Educational level	≤ high school	115 (61.5)	0.003
	≥ Graduate	589 (72.4)	

**Note:** \*P-values and percentages were calculated based on the number of participants indicated in Table 1

**Table 5:** Knowledge of the presence of acetone-free nail lacquer remover in relation to demographic characteristics (n = 1001)

Characteristic		Frequency (yes) n (%) <sup>*</sup>	*P-value
Gender	Male	46 (19.2)	0.007
	Female	204 (26.8)	
Age (years)	18 – 25	175 (28.4)	0.025
	26 – 35	41 (20.2)	
	≥ 36	34 (18.7)	
Educational type	Health-related	166 (32.4)	0.000
	Non-health-related	84 (17.2)	
Educational level	≤ High school	34 (18.2)	0.038
	≥ Graduate	216 (26.5)	

**Note:** \*P-values and percentages were calculated based on the number of participants indicated in Table 1

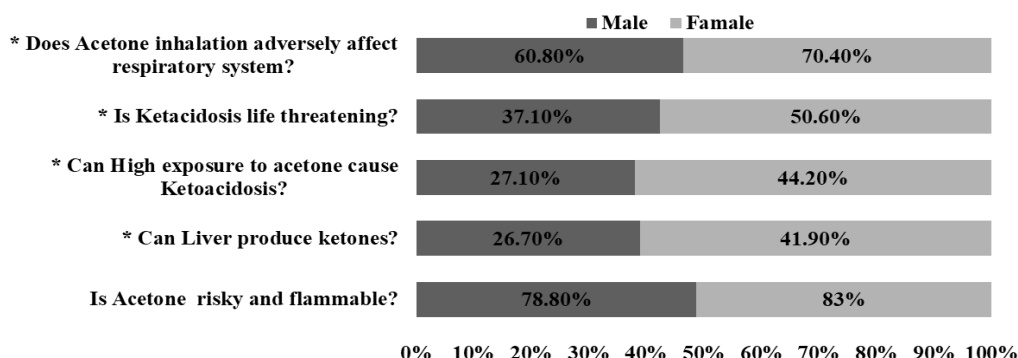
### Participants' awareness of the association between ketoacidosis and the use of acetone-containing products

The results in Table 6 reveal that majority of participants were aware of the toxicity of these products if inhaled (68.13 %) or exposed to flame sources (82.902 %). Unfortunately, findings also showed that not many of the participants were aware of the risks and health hazards of ketoacidosis. Only 40.06, 38.26 and 47.35 % of participants were aware of the risk of developing ketoacidosis, raised liver ketone levels, and the associated hazards to life, respectively, due to high degree of exposure to acetone-containing

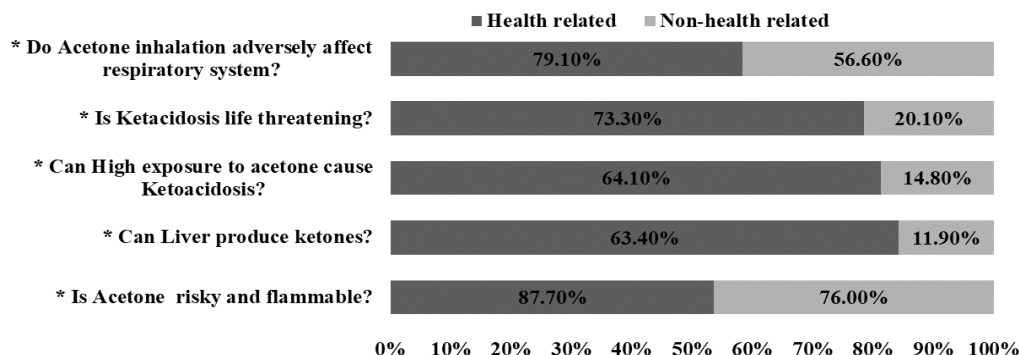
products. As illustrated in Figure 1, comparison between the two genders revealed that majority of the females showed adequate awareness about the hazards associated with inhalation of acetone-containing products and the risk of flammability (70.4 and 83 %, respectively;  $p < 0.05$ ). Similarly, 44.2, 41.9 and 50.6 % of the females were significantly aware of the risk of developing ketoacidosis, increased liver ketone levels, and the associated health hazards, respectively, due to high exposure to acetone-containing products, relative to their counterparts who showed deficiency of awareness about these risks ( $p < 0.05$ ).

**Table 6:** Awareness of the ketoacidosis associated with high exposure to acetone-containing products (n = 1001)

Question	Frequency (yes); n (%)
Does acetone inhalation adversely affect the respiratory system?	682 (68.13)
Is acetone risky and flammable?	821 (82.02)
Can high exposure to acetone cause ketoacidosis?	401 (40.06)
Is ketoacidosis life-threatening?	474 (47.35)
Can the liver produce ketones?	383 (38.26)



**Figure 1:** Comparison of the awareness about ketoacidosis linked to high exposure to acetone-containing products, based on gender of participants. **Note:** \* $P < 0.05$ . The % values were calculated based on the number of participants indicated in Table 1

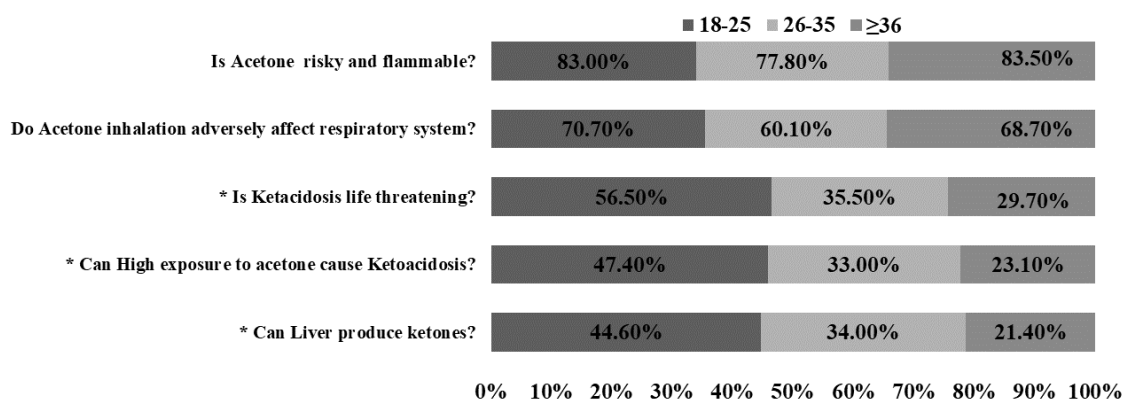


**Figure 2:** Influence of health-related education on awareness of ketoacidosis linked to high exposure to acetone-containing products. **Note:** \* $P < 0.05$ . The % values were calculated based on the number of participants indicated in Table 1

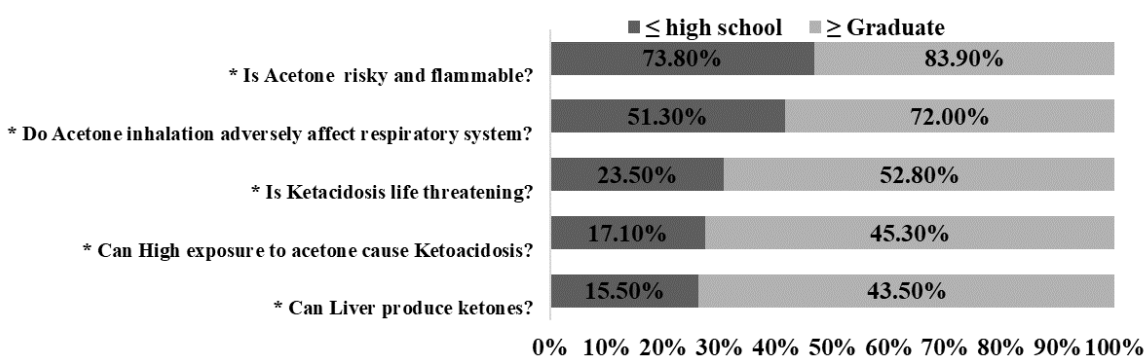
Assessment of differences in level of awareness about the safe use of acetone-containing products and the risk of ketoacidosis associated with the use of these products as a function of participant's educational type is shown in Figure 2. Majority of participants with health-related education showed significantly adequate awareness about the hazards associated with inhalation of acetone-containing products (79.1 %) and the risk of flammability (87.7 %;  $p < 0.05$ ). In addition, 64.1, 63.4 and 73.3 % of participants with health-related education were significantly aware of the risk of developing ketoacidosis, raised liver production of ketones, and the associated life hazards, respectively, due to high levels of exposure to acetone-containing products, relative to their counterparts who

showed deficiency of awareness about these complications ( $p < 0.05$ ).

With respect to differences in awareness level based on age groups of participants, majority of subjects in the youngest age group aged 18-25 years had significant ( $p < 0.05$ ) awareness regarding the hazards associated with inhalation of acetone-containing products and the risk of flammability (70.7 and 83.0 %, respectively; Figure 3). In addition, only 47.4, 44.6 and 56.5 % of the youngest participants were significantly aware of the risk of developing ketoacidosis, increased liver ketone levels, and the associated health, respectively, due to high exposure to acetone-containing products, when compared to participants in other age groups ( $p < 0.05$ ).



**Figure 3:** Comparison of awareness of ketoacidosis linked to high exposure to acetone-containing products, based on participants' age groups. **Note:** \* $P < 0.05$ . The % values were calculated based on the number of participants indicated in Table 1



**Figure 4:** Comparison of awareness of the ketoacidosis associated with high exposure to acetone-containing products based on participants' educational level. **Note:** \* $P < 0.05$ . The % values were calculated based on the number of participants indicated in Table 1

Results based on educational level of participants (Figure 4) showed that majority of the participants with graduate degrees or higher were significantly ( $p < 0.05$ ) aware of the hazards associated with inhalation of acetone-containing products and the risk of flammability (72.0 % and 83.9 %, respectively). However, many of participants showed poor knowledge of ketoacidosis (Table 6). Indeed, only about half of the participants with graduate degrees or higher were significantly ( $p < 0.05$ ) aware of the risk of developing ketoacidosis, liver ketone production, and the associated hazards to life (45.3, 43.5 and 52.8 %, respectively) due to high degree of exposure to acetone-containing products, while their counterparts showed poor awareness of these risks.

## DISCUSSION

Nowadays, the use of nail cosmetics and lacquers is a common practice, especially among younger females [3]. Arising from the fact that acetone is present in synthetic personal care and household products, there is quite a bit of confusion surrounding its safety [7,8]. Yet, there

is insufficient investigation of the knowledge and awareness of users with respect to nail products and their chemical compositions [1,4,9]. To the best of our knowledge, this study is the first to investigate participants from the public (regardless of their profession, gender, educational type and level), focusing on the knowledge and awareness of risks associated with acetone-containing nail lacquer removers and sterilizing products.

The findings are in agreement with results from a previous and similar work conducted in Lebanon which was targeted at Lebanese women salon workers [15]. The study reported that young women with high school education or beyond were more knowledgeable about the hazardous and harmful effects of acetone, but had poor/fair knowledge about health hazards associated with chemical compounds (including acetone) used in nail cosmetics. In the present study, the findings showed that participants were significantly knowledgeable about the presence of acetone in nail lacquer removers and sterilizing products. However, only minority of participants were aware of the availability of acetone-free nail lacquer remover in the market. Alternative

acetone-free removers are widely available and largely consist of gamma-butyrolactone (GBL). Although it is accepted that the latter is safer, case reports have shown that it may be toxic and may cause serious side effects [6].

Investigations on the public awareness of the dangers of high-level exposure to acetone-containing products revealed that participants had moderate awareness of these hazards, with a significantly lower level of awareness observed among non-graduate participants. It is well known that the compounds used in nail products may become aerosolized, thereby leading to respiratory, skin and neurological diseases, and more serious complications [1,4,8]. Many participants with health-related education were aware of the physiological production of ketones by the liver, while other participants showed a significantly poor level of understanding of this physiological process. It is well known that the human body produces ketones through the breakdown of body fats, via exposure to air, water, or food contaminated with acetone, or as a by-product of metabolism [16].

Investigations on awareness regarding the health hazards of ketoacidosis associated with excessive exposure to acetone-containing products revealed poor awareness levels among participants. It is well known that ketoacidosis which is a common condition among diabetic patients, is different from alcoholic ketoacidosis which occurs in patients with a history of chronic alcohol use [10]. A clinical review [11] has revealed that clinicians need different emergency strategies and interventions for the evaluation and management of symptoms of toxicity cases caused by alcohol exposure, relative to diabetes-caused cases. Such strategies include essential care for these patients.

In this study, participants who had health-related education, graduates, and subjects in the younger age group, were significantly more aware of the health hazards and the risk of ketoacidosis associated with human exposure to acetone-containing products, relative to other groups. Therefore, educational level and illiteracy were identified as important issues that influence awareness and knowledge regarding acetone-caused toxicity [17]. These findings are of interest to policymakers in the healthcare field in general, and they are important to educators in the healthcare education sectors, in particular. Therefore, improvements in academic programs and course outcomes are important to enhance graduates' capacity to play important roles in risk assessment and increase public awareness of the potential health hazards associated with

commonly used chemical products. Therefore, chemicals and products that are usually underestimated as being generally safe and with minimum risk of harmful effects, need to be reconsidered as health risk agents.

### **Study limitations**

The main limitation of this study was the difficulty in collecting a high number of responses from the population during the study period which was at the beginning of the COVID-19 pandemic. The problem was either that many of recipients did not care to respond or that they did not have access to internet connection. Moreover, some of the male participants refused to fill out the questionnaire as they are of the view that acetone nail polish removers are exclusively for female use. Another limitation is the dearth of information or data in the literature regarding toxicity cases caused by exposure to acetone-containing products.

### **CONCLUSION**

This study showed poor awareness of the health hazards of developing ketoacidosis associated with human exposure to acetone-containing products among the Jordanian population. Consequently, more attention should be paid to the potential toxicity and health hazards caused by these products. In this context, educational programs, health-related graduate training sections, and public campaigns should be implemented with the aim of improving public awareness regarding the toxicity associated with common organic solvents.

### **DECLARATIONS**

#### **Acknowledgement**

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#### **Funding**

None provided.

#### **Ethical approval**

Approval was obtained from the Institutional Review Board (IRB) at Yarmouk University, Jordan (der/2024/360).

#### **Conflict of Interest**

No conflict of interest associated with this work.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Contribution of Authors

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them.

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