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Investigation of chromated copper arsenate-treated waste wood used for bedding material in the Hokkaido area

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Abstract

Chromated copper arsenate (CCA)-treated wood has prompted public concern regarding the contamination of livestock-rearing environment. We investigated the current status of CCA-treated waste wood used as bedding material for livestock in the Hokkaido area. Two-step surveys with structured question and purposive sampling were conducted to clarify the current status of wood-based bedding materials for contamination of CCA compounds in farms. The analyses of CCA compounds with an atomic absorption spectrometer indicated unusually high concentrations of chromium, copper, and arsenic in some bedding materials. These findings suggest that ca. 2 % (n = 84) of bedding materials for livestock are most likely contaminated with CCA-treated waste wood in the Hokkaido area.

Key Words: Bedding material; CCA-treated woods; Toxic elements

Wood-derived chips, pellets, mulch, and other shredded products are used for various purposes. In the livestock sector, they are often used as bedding materials for animals. Building construction and demolition (C&D) wood may also be reduced to chips for these purposes[5,6,13]. The Basic Law for Establishing the Recycling-based Society (Construction recycle law) was enacted in 2000, mandating the sorting and recycling of C&D wood address the large amount of such waste generated annually in Japan[14]. In the Hokkaido area, a total of 210 Gg of chipped wood is produced annually, with about 80 Gg used as bedding material[17]. To ensure the efficient usage of used wood resources, promoting recycling activities is vital. However, C&D wood may contain CCA-treated wood, which should be disposed off as industrial waste and not reused. CCA is a chemical wood preservative containing chromium, copper, and arsenic.

In Japan, CCA-treated wood material were used from 1963 to 1996 when it was standardized within Japanese Industrial Standards (JIS) as wood preservatives and ceased production in

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2003. The average lifespan of Japanese wooden buildings is about 30 years[15]. These CCA-treated buildings are likely to be demolished in the near future which will subsequently comingled with waste and increase the amounts of CCA-treated C&D materials in recyclable materials. The use of this CCA-treated C&D material as recycled wood may thus result in unintended exposure.

Unfortunately, separating non-recyclable C&D wood from recyclable wood is difficult; while companies are legally obliged to sort C&D wood materials properly, older C&D wood may have dark discoloration, which makes the sorting process more difficult. This difficulty with visual inspection may raise some concerns of potential contamination of CCA-treated non-recyclable C&D materials among non-CCA-treated recyclable C&D wood materials.

To address this problem, Hokkaido Forest Products Research Institute has initiated a simplified sorting process for CCA-treated wood materials using specific chemical coloration testing for CCA elements[16]. A number of measurement devices with optical sensors for detecting CCA compounds in the wood have also been developed; however, the initial financial investment in these devices is rather substantial. Given the above, promoting the regular use of these sorting processes is difficult.

In Germany, the concerns about accidental CCA exposure due to the usage of CCA-treated wood material in particle board for furniture and other indoor features has necessitated the enactment of a law to limit the level of CCA in recycled wood material[9]. In the United States, major concerns were raised regarding the potential for exposure to CCA compounds in children and ground water contamination due to the use of CCA-treated C&D materials as mulch in playgrounds, parks, and home gardens[1,5,10,11]. Although CCA-treated C&D materials ought to be disposed of as industrial waste, improper storage practices lead to the contamination of the ground water[4,8,9].

The CCA compounds are known to have various toxic effects[2]. For example, chronic exposure to arsenic (As) induces cytogenetic damage, the element is considered a clastogenic and aneugenic carcinogen[3]. In addition, As exposure in pregnant animals can cause prenatal harm, which may result in induction of hepatic, ovarian, pulmonary and adrenal tumors in adult mice[12]. There are many livestock farms in the Hokkaido area with wood-derived bedding material. If CCA-treated C&D wood material is used in livestock-rearing environments, there is a risk that the animals' health may be degraded—with an accompanying reduction in the quality of the animal meat products. In order to safeguard and maintain the public health, it is important to avoid consuming CCA-contaminated meat and dairy products. In the present investigation, we examined the amount of CCA-treated wood material being used livestock bedding material in the Hokkaido area.

Our study was conducted as a 2-stage survey with structured questionnaires. 500 livestock farms in the Hokkaido area were surveyed with the main livestock type, farm size, and type of bedding material and the second stage with purposive sampling for farms use wood derived bedding materials.

In the second stage, we asked more detailed questions about the type, usage, and handling of bedding materials for livestock. We also requested that respondents donate a sample of their bedding material to be tested for CCA compounds.

After the bedding material samples were received, they were dried for at least 24 h with a forced-air dryer at 80°C in order to achieve a constant mass, in accordance with the method of Kuboi[18]. After drying, 5 g-dw of each sample was homogenized using a Wonder Blender (Waring Co. Torrington, CT, USA) for 30 sec to reduce the sample to a powder form. A 0.2 g-dw sample of the powder was placed in a 10-ml PTFE (polytetrafluoroethylene) test tube and then mixed with 2 ml of concentrated nitric acid (61%) and 1 ml of concentrated hydrogen peroxide (60%). The PTFE test tube was heated at 150°C for at least 1 h without a lid to extract the CCA compounds

Table 1. Bedding material types, sample numbers (%) and concentrations of CCA measured [median (range)] in μg/g-dw

Types	n (%)	T-Cr.	T-Cu.	T-As.
Sawdust	52 (62 %)	2.8 (BDL[a)]–20.2)	3.3 (1.2–15.2)	0.3 (0.1–1.5)
Bark	11 (13 %)	10.7 (0.8–83.2)	7.8 (3.3–91.8)	1.2 (0.3–14.1)
Shaving dust	8 (10 %)	3.3 (0.8–4.8)	4.4 (2.2–11.8)	0.4 (0.2–1.8)
Chip	6 (7 %)	7.9 (1.5–22.2)	8.1 (2.5–72.9)	6.6 (0.4–13.9)
Husk	4 (5 %)	17.4 (9.8–24.1)	3.8 (3.4–4.8)	1.7 (1.3–1.8)
Straw/dry grass	3 (4 %)	7.5 (3.5–19.1)	3.9 (3.6–4.7)	1 (0.5–1.1)

a) Below detection limit

from the bedding samples. After extraction, the volume was adjusted to 2 ml using double-deionized water, and then the sample solutions were analyzed with an Atomic Absorption spectrometer (AA-800; Perkin Elmer, Waltham, MA, USA) to determine the concentrations of total chromium (T-Cr), total copper (T-Cu), and total arsenic (T-As); all analyses were conducted in duplicate and evaluated. The duplicated measurements were repeated until the differences in the duplicated values became $< 10\%$.

Among the 500 farms initially surveyed, we received replies from 242 (response rate of approximately 48%). From those 242, we selected the 91 who were using wood- or plant-based bedding materials for the second survey. We then received 57 responses at the second stage (response rate of approximately 63%), and 84 samples of bedding material were collected for the analysis. The farming types and numbers were 58 (69%) dairy farms, 24 (29%) beef cattle farms, and 2 (2%) combined dairy and beef cattle farms. Of the 57 farms, 20 (approximately 35%) were using combined bedding materials.

Table 1 shows the type of bedding materials, sample numbers, percentages, and concentrations of T-Cr, T-Cu, and T-As. The ranges of measured values from the bedding materials ranged from below detection limit (BDL)-83.2 μg/g-dw for T-Cr, 1.2–91.8 μg/g-dw for T-Cu, and 0.1–14.1 μg/g-dw for T-As. Among the three elements, T-Cr and T-Cu concentrations were > 5 μg/g-dw in 25 samples, and T-As > 1 μg/g was found in 26 samples.

In the second survey, CCA compounds were detected in the bark and chip bedding materials. This suggests that CCA-treated C&D wood materials were used by livestock farmers in Hokkaido as bedding materials. Shaving dust showed lower values of Cu and As than chip bedding materials. However, some values were higher than in the chip samples. For the highest concentrations of Cr, the sawdust, chip, husk, and straw showed approximately 20 μg/g-dw, which was higher than the concentrations in shaving dust (4.8 μg/g-dw).

No regulatory value has yet been established for CCA elements in recycled wood materials in Japan. However, there are regulatory values for CCA compounds in recycled wood products in Germany, as follows: Cr < 30 μg/g-dw, Cu < 20 μg/g-dw, and As < 2 μg/g-dw[9]. These values were compared with the findings from the bedding materials examined in this study. We found that 2 (2%), 3 (4%), and 9 (11%) samples exceeded the German regulatory values for Cr, Cu, and As, respectively. As had the highest concentration and exceeded the regulatory values. This is a rather alarming result, as these elements may significantly affect the health of livestock exposed to CCA-contaminated bedding materials.

As is reported to have the strongest toxic effect among CCA compounds[2], so it is particularly important to monitor the amount of As in livestock bedding materials. However, the amounts of Cr and Cu should also be monitored, in order to detect the concentration in CCA-treated wood contamination used in bedding materials. Of note, the ratios of CCA element

Plate 1. Analyzed bedding materials. a, Bark. b, Chip.

concentrations in the examined samples were not consistent, which may be due to the mixture ratio of each element in the CCA chemicals during the manufacturing process[13]. A previous investigation also reported that different CCA compounds have different rates of leaching from the wood materials into the soil[7,8], and temperature and humidity may also play a crucial role in the rates of leaching.

The bedding materials with relatively high concentrations of CCA compounds—bark and chip—are shown in plate 1a and b. In contrast to these high concentrations, sawdust and shaved wood showed relatively low CCA concentrations. The discrepancy can be adduced with to the use of byproducts of cutting and/or other processes derived from newly logged trees, rather than recycled wood. In the plate 1a, we can see that the bark sample may intrinsically have a dark color. In addition, the outer surface of some processed tree materials may change to a darker color due to direct exposure to the atmosphere and contact with soil and/or dust, which is a common characteristic of C&D wood materials. However, as shown in the plate 1b, the chip sample has a brighter color, which makes it more difficult to realize that this is derived from C&D wood material. The chip samples showed high median concentrations of T-As (6.6 μg/g-dw) and relatively high values of T-Cr (7.9 μg/g-dw) and T-Cu (8.1 μg/g-dw), suggesting that these samples might be C&D materials treated with CCA. These results indicate that the appearance of freshly processed wood materials can be deceptive, and identifying CCA-treated materials can be difficult based on a visual inspection alone. While using C&D materials contaminated with CCA-treated wood is illegal, this investigation nevertheless revealed possible contamination of such material with CCA compounds. From a previous study, CCA element concentrations measured in a straw sample were 0.24–0.38 μg/g-dw (Cr), 3–4 μg/g-dw (Cu), and 0.28–0.30 μg/g-dw (As)[19]. The concentration ranges of straw/dry grass determined from this study were 3.5–19.1 μg/g-dw (T-Cr), 3.6–4.7 μg/g-dw (T-Cu), and 0.5–1.1 μg/g-dw (T-As). Therefore CCA values observed in this study were higher than the values mentioned by the Houba *et al*. (1994).

Among the CCA compounds, the concentrations of As exceeded the German standard value. The health risks associated with As residue in dairy products might have a negative impact on human health. Therefore, monitoring the long-term health effects of CCA exposure in livestock is important.

Based on the responses to our survey, there were no reports of clinical signs of toxic effects from farmers using the bedding materials suspected of CCA contamination. In addition, contaminated bedding material may also adversely affect the environment. Inappropriate disposal of bedding materials contaminated with CCA compounds may leach from the bedding material into the surrounding soil and aquatic system, which can affect the ecosystem integrity. Furthermore, if the bedding material is mixed with manure and used as compost, it can slow down the composting process because of the excellent anti-decomposing function of CCA chemicals.

The elements in CCA all have different toxicities and different oxidation states. For example, As may have a different oxidation status under different pH conditions, as arsenate (V). Previous studies have reported that CCA components can leach from mulch being used on the ground surface to contaminate groundwater system[1,10,11]. Once As reaches the water system, it can then spread, potentially reaching a more reduced aquifer where it can change to arsenate, a more toxic form.

Furthermore, when farmers cannot use all of the compost they produce, it is common practice to supply the excess to nearby crop fields and/or horticultural farmers. In this case, the distribution of CCA compounds becomes even more widespread. As such, it is important to increase awareness of the threat to public health posed by CCA-contaminated bedding material.

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