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A Survey-Based Analysis of the Extent of Aluminium Involvement in our Lives for Risk Assessment

Singh Gupta Supriya* and Gangurde Pradnya

HPT Arts and RYK Science College, Nasik - 422005, Maharashtra, India; singhguptasupriya@gmail.com

Abstract

Despite being a non-essential metal in the body, we acquire aluminium via various sources such as aluminium cookware, foil, medicines, cosmetics, food, water, and aluminium-industries. Though it can be eliminated from our body, the excess and cumulative effect can't be ignored. Aluminium load above the threshold causes several diseases like Alzheimer's, osteomalacia, anaemia, and cancer. Hence, the current study was designed to explore the frequency of aluminium usage in various forms in the Indian population of northwest rural and urban regions of Maharashtra and investigate any preferential difference in aluminium usage with occupation, education, income, and family structure. It is a correlational study designed to check the extent of aluminium involvement in their lives and their perception of awareness. A non-random sampling method using social media was utilized for data collection, and data were analyzed using a statistical tool, Jamovi. A survey-based analysis of the responses to a pre-designed questionnaire was done. The prominent factor contributing to the aluminium load was found to be the aluminium vessel used in our kitchen. Boiling, storing, and baking edible items facilitate its leaching into food to toxic levels. Further analysis revealed a significant correlation of financial and educational status with aluminium usage. Reducing aluminium vessel usage for cooking can significantly reduce aluminium load in our bodies. However, we still need to be vigilant about the aluminium load which the other products are imparting upon us. Hence, awareness and exploring the alternatives are the only options to keep a check on the aluminium load.

Keywords: Aluminium Load, Aluminium Vessels, Cooking, Metal Toxicity

1. Introduction

Aluminium (Al) is one of the most abundant metals in the earth's crust. The industrial applications of aluminium have revolutionised our lives and have made it an indispensable part of our daily routine. Despite no biological role and low bioavailability of aluminium[1], humans have managed to incorporate this non-essential element as an integral part of the human body.

Interest concerning the levels of aluminium in the human body increased after the establishment of its correlation with certain medical complications such as osteomalacia[2], cancer[3,4], reproductive system toxicity[5], Alzheimers[6,7], etc.

Literature surveys suggest that different natures of aluminium exposure act independently but may contribute cumulatively to aluminium toxicity in humans. One of the many factors of aluminium exposure seems to be in an Indian kitchen, as aluminium vessels are a part of household items in India[8]. Multiple properties of aluminium, such as its lightweight, good heat conductors, and inexpensive and non-sticky nature, have made it a vessel of choice for cooking purposes. The extensive aluminium usage in cooking has made it a daily component of our diet due to its leaching into food[9]. Likewise, Aluminium foil is quite popular for its usage in baking, grilling, and food packaging which contributes to aluminium leaching into food[8,10].

**Author for correspondence*

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Apart from aluminium cooking vessels, other sources augment the aluminium load in the human body further. Drinking water is one such, where aluminium compounds are used as a coagulant in the water treatment process, which increases its aluminium content[11]. Furthermore, canned beverages and preserved food (frozen pizza and cake mix) also contribute to aluminium exposure[12]. The acidic content of soft drinks facilitates aluminium leaching from cans in drinks, which is further elevated by the increased period of storage time[13]. Likewise, certain medicines (antacids) and vaccines (DPT)[14] have aluminium compounds and are reported to cause osteomalacia[2] and neural complications[15], respectively.

Moreover, the dazzling world of cosmetics, including lipsticks[16], antiperspirants[17], shampoo[18], and eye shadow[19], also contribute to aluminium exposure. Above all, the baby formula feed has also been reported for its toxicity due to the aluminium content in it[20]. However, the people working in aluminium-based metallurgical industries get the maximum exposure and are reported to exhibit neurological complications[6].

This suggests that aluminium exposure from different sources contributes independently to the aluminium load in the human body. Hence, the present study is an effort to see the extent of aluminium involvement in our day-to-day life and identify the probable factors responsible for aluminium load in the human body by using survey-based analysis for a small population of northwest rural and urban regions of Maharashtra. The survey form was designed to fulfil two significant objectives. First, to explore the frequency of aluminium usage in various forms concerning the Indian population and second, to investigate the differences in the use of aluminium between the categories of gender, occupation, education, income, and family structure.

2. Methods

2.1 Type of Study

This study was a correlational research design to check the extent of aluminium involvement in their lives from different sources and their perception of awareness. It is a descriptive form of research done by non-random sampling to have an unbiased representation of the total population.

2.1.1 Methods of Data Collection

The questionnaire-based survey acquired primary data from a mixed population of Nasik District from different backgrounds. Social media (Whats App) was used for the data collection. An elaborate questionnaire was prepared on Google form and the link was circulated. A total of 246 responses were included in the study.

Internet was used as a source to collect secondary data, because of its limitless networking of resources. Google Scholar was extensively used to locate numerous online databases to find related articles. Data was collected from published literature on aluminium toxicity from previous decades. The selection of the data was based on the quality of the content and the relevance to the topic.

2.1.2 Questionnaire

The questionnaire included three sections- Section 1 with demographic details, and Section 2 with five questions of multiple correct answers. Section 3 included 16 questions with a response on a 5-point Likert scale, except the 16th question, which is a multiple-choice question and is represented in graphical form along with 5 questions from Section 2 (Please refer Appendix).

2.1.3 Data Analysis

The data collected was analyzed using the statistical analysis software, Jamovi 1.6.23. The demographic data in Section 1 was subjected to frequency analysis. Section 2 explored the frequency of aluminium usage in various forms concerning the Indian population by performing frequency analysis while achieving our first objective. The assessment of the extent of aluminium involvement in an Indian population in the Maharashtra region was depicted in Section 3 using the Likert Scale.

The second objective was achieved by comparing aluminium usage parameters in Section 3 between demographic groups. To achieve this, the data in Section 3 was obtained on an ordinal scale. Hence, the non-parametric test Mann-Whitney U test was performed where the demographic details having two options were compared, such as area (urban or rural), gender (male or female), or family size (nuclear or joint), with the responses in Section 3. Similarly, a one-way ANOVA Kruskal-Wallis test accompanied by Dwass-Steel-Critchlow-Fligner (DSCF) pairwise comparison was used to compare the demographic details having multiple

options such as educational status or financial status with the responses in Section 3.

3. Interpretation of Data/Results

The frequency analysis of demographic details in Section 1 is shown in Table 1. Later the data in Section 2 was analyzed by finding a frequency analysis of individual responses for every question and is represented as clustered charts in Figure 1.

This reflects the usage of aluminium by the Indian population. Despite the proven toxicity of aluminium vessels, 75% of people are using them for cooking (Figure 1(A)), 59% for storing cooked food in these (Figure 1(B)), and 68% for cooking their vegetables (Figure 1(C)).

Table 1. Data showing the frequency analysis of the demographic details in Section 1 of the questionnaire

	Counts	% of Total	Cumulative %
Gender			
Female	178	72.4 %	72.4 %
Male	68	27.6 %	100.0 %
Occupational Status			
Not working	164	66.3 %	66.3 %
Working	83	33.7 %	100.0 %
Educational Qualification			
Diploma	17	6.9 %	6.9 %
Graduate	68	27.6 %	34.6 %
HSC	51	20.7 %	55.3 %
Post Graduate	42	19.1 %	74.4 %
SSC	63	25.6 %	100.0 %
Annual Income of Family			
Above 10 lakh	18	7.3 %	7.3 %
Below 1 lakh	145	58.9 %	66.3 %
Between 1 to 5 lakh	66	26.8 %	93.1 %
Between 6 to 10 lakh	17	6.9 %	100.0 %
Residential Location			
Rural	75	30.5 %	30.5 %
Urban	171	69.2 %	100.0 %
Type of Family			
Joint	84	34.1 %	34.1 %
Nuclear	162	65.6 %	100.0 %

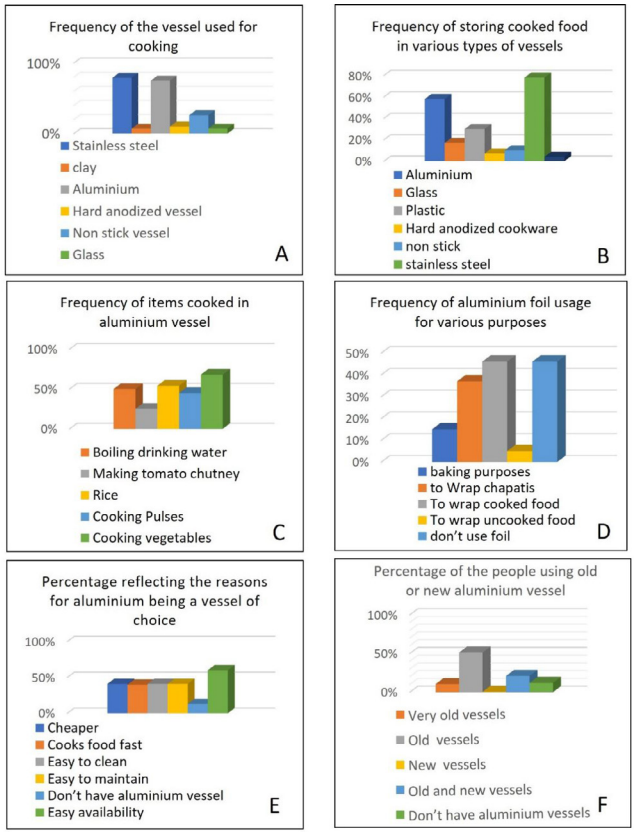

Figure 1. **(A)** Graphical representation of frequency of vessels used for cooking. **(B)** Graphical representation of frequency of storing cooked food in various types of vessels. **(C)** Graphical representation of frequency of items cooked in aluminium vessels. **(D)** Graphical representation of frequency of aluminium foil usage for various purposes. **(E)** Graphical representation of the reasons for aluminium being a vessel of choice. **(F)** Graphical representation of percentage of people using the new and old aluminum vessels.

However, very few people are using aluminium foil for baking their food (Figure 1(D)). The reason seems to be cheaper cost, faster cooking, easy availability, maintenance, and cleaning (Figure 1(E)). Moreover, the majority of the population is using old aluminium vessels for cooking (Figure 1(F)).

The data in Section 3 was further analyzed to know more about the extent of aluminium involvement. Surprisingly, despite known facts regarding aluminium toxicity, not much attention has been drawn to aluminium usage at a domestic level. This Likert Scale data has been visualized by using diverging bars with neutrals separate in Figure 2. This representation reflects an alarming situation, as very few responses are towards

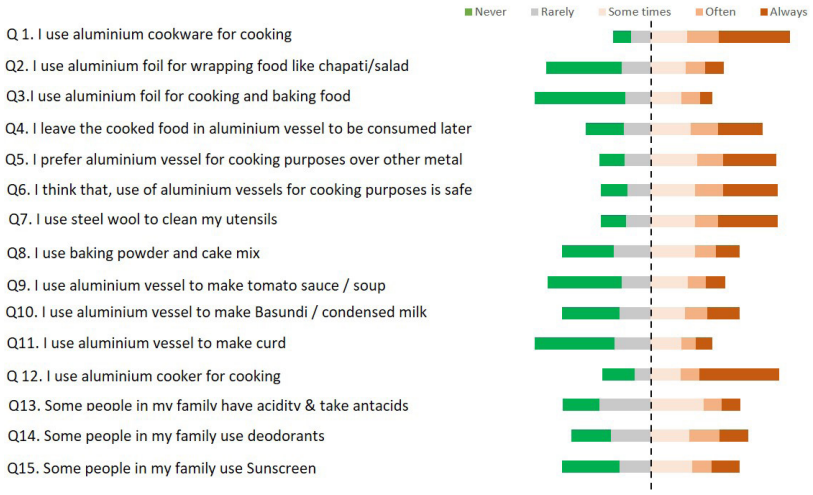

Figure 2. Visualizing Likert Scale data using diverging bars with neutral separate to represent the extent of aluminium involvement in our lives.

never and rarely for aluminium involvement. Moreover, the involvement of aluminium vessels for cooking seems to be the dominant factor contributing to the aluminium load in the current study.

As the findings guided us further, the responses to various questions in Section 3 were used to establish any significant correlation with the groups (under the demographic section) in Section 1. This comparison was made in two parts.

The first part includes a detailed comparison of the demographic details (With only two options), like Area and Family, with the responses in Section 3 of the form. The gender-wise comparison was excluded due to no significant difference. Findings suggest that people in rural areas leave cooked food in an aluminium vessel and use steel wool to clean vessels more (Table 2). Similarly, there is more usage of baking powder and cake mix by people living in joint families (Table 3).

In part two, the demographic data of Section 1, with more than two options, (family income and educational status) were compared with the responses in Section 3. The result summarizes that educational and financial status defines our choices of vessels to be used for cooking (Tables 4 and 5). The highly educated group and financially stable group show limited usage of Aluminium vessels.

Table 2. Mann-Whitney U test with grouping variable area (Rural and Urban)

Mann-Whitney U Test		
	Mann-Whitney U Test	
	Statistic	**P**
I leave the cooked food in an aluminium vessel to be consumed later	4689	<.001
I use steel wool to clean my utensils	4748	<.001

Table 3. Mann-Whitney U test with grouping variable family (Joint and Nuclear)

Mann-Whitney U test		
	Mann-Whitney U Test	
	Statistic	**p**
I use baking powder and cake mix	5098	<.001

4. Discussion

This omnipresence of aluminium in our environment cannot be ignored. Moreover, its usage in our day-to-day lives has increased our exposure to this non-essential metal. Various studies have concluded that aluminium exposure via medicines[2,14], cosmetics[16-19], canned carbonated drinks and preserved food[12,13], drinking water[11], aluminium cookware[9], aluminium foil[8,10], baby formula feed[20], and various aluminium-based industries[6] have allowed the aluminium to reach our body through different routes[21]. Various parallel studies have been taken up to support the harmful effects of aluminium in humans, like its role in neural toxicity[6], Alzheimer's[7],

Table 4. One-Way ANOVA (Nonparametric) with grouping variable as educational qualification

Kruskal-Wallis			
	χ^2	Df	P
I use aluminium cookware for cooking	24.3	4	<.001
I use aluminium foil for wrapping food like chapati/bread / salad	27.6	4	<.001
I use aluminium foil for cooking and baking food	23.7	4	<.001
I leave the cooked food in an aluminium vessel to be consumed later	31.0	4	<.001
I prefer aluminium vessels for cooking purposes over vessels of other metal	27.8	4	<.001
I use baking powder and cake mix	36.5	4	<.001
I use an aluminium vessel to make Basundi / condensed milk	28.2	4	<.001
I use an aluminium cooker for cooking	24.4	4	<.001

Table 5. One-Way ANOVA (Nonparametric) with grouping variable as family's annual income

Kruskal-Wallis			
	χ^2	Df	P
I use aluminium cookware for cooking	24.5	3	<.001
I leave the cooked food in aluminium vessel to be consumed later	29.0	3	<.001
I prefer aluminium vessel for cooking purposes over vessels of other metal	21.3	3	<.001
I think that the use of aluminium vessels for cooking purposes and another household usage is safe	20.6	3	<.001
I use aluminium cooker for cooking	20.5	3	<.001

osteomalacia[2], and cancer[3,4]. However, the amount of aluminium exposure given by all the sources mentioned above has been questionable till now, and still, there is no significant finding that this amount is enough to cause any actual harm. As a substantial amount of aluminium is eliminated via the kidney in urine and some via the gastrointestinal tract in faeces, its impact on health has been ignored[22]. However, it has been reported that people with renal failure or dysfunction and those with some gastrointestinal tract issues cannot eliminate this and are majorly affected by the aluminium-based disorder in the body. This excess aluminium is deposited in various tissues, including bone, brain, liver, heart, spleen, and muscle[22].

Despite this, not much focus has been provided on these aluminium sources and their exposure. Moreover, we have failed to consider the cumulative effect of all these sources. However, our survey has shed some light on the exposure to aluminium in our daily lives.

As per our findings, the most common factor contributing to the aluminium load seems to be the aluminium utensils as several people are using these for cooking purposes. The reason for this was its cheaper cost, capacity to cook faster, and easy maintenance. Moreover, Indian cuisine involves cooking at high temperatures, elaborate time (condensed milk), making sour things like tomato chutney, and storing the cooked food in an aluminium vessel. Such practices are statistically significant and increase aluminium leaching[23]. In 2000, Bamji and Kaladhar also reported that the leaching of aluminium from cooking vessels is a major cause of aluminium burden in the Indian population[24]. Moreover, recently a correlation between cooking food in aluminium vessels and the onset of Alzheimer's has been established in the Indian population of the Vadodara Region, Gujrat[25]. Nonetheless, the boiling of drinking water in an aluminium vessel was also found significant in our data which is known to facilitate aluminium's leaching in water[26]. Our findings suggest that only a few people are using aluminium foil for baking purposes, which is a relief as baking releases more aluminium in food[10]. Another finding revealed the fact that the majority of people are using old aluminium vessels for cooking, which comes in our favour as older aluminium vessels leach less aluminium in food[23].

This survey also provided us with specific significant correlations between the groups and responses, people with, rural backgrounds, low educational status, and lower income are using the aluminium vessels more frequently and are storing cooked food in them as shown in Tables 2, 4, and 5, respectively. Moreover, people in rural areas are using steel wool more frequently to clean their aluminium utensils which enhances the aluminium leaching further into food[27]. Similarly, people in joint families are using more premixes of cake for baking, which could be justified by their higher engagement levels. These findings suggest that people are unaware of the adversity caused by prolonged and excessive usage of aluminium.

Though substantial levels of Aluminium can be eliminated by a healthy human body, a study has shown aluminium toxicity in healthy people also[6]. Hence, vigilance on aluminium uptake from various sources

is needed. Therefore, the best option is to replace these aluminium-based products with the available non-aluminium alternatives. Like, aluminium vessels can be replaced by steel, glass, clay, or iron vessels. Additionally, iron vessels increase the iron content in our food which is further enhanced by storing the food in it and this would help in mitigating the iron deficiency in people[28].

Similarly, other things which contribute to the aluminium load in our body can also be replaced. A cotton cloth can replace aluminium foil for wrapping food. Aluminium coagulant can be replaced by Moringa seed powder for water treatment[29]. Likewise, the cosmetic industry can use Kaolin, white clays, or guanine, a compound from fish scale as an alternative to aluminium powder[19]. Similarly, calcium-based compounds can replace aluminium compounds in certain vaccines (as adjuvants) and antacids[14]. Hence, a comprehensive approach is required to avert the aluminium toxicity daily.

5. Conclusion

Our findings suggest that the foremost aluminium exposure comes from the usage of aluminium vessels for cooking and storing food in the Indian kitchen and immediate replacement of aluminium vessels will play a crucial role in reducing the aluminium load in the human body. However, we still need to be vigilant about other aluminium-containing products which we often use. Hence, it can be consolidated that awareness can help in curtailing the daily aluminium load by exploring the alternatives for aluminium-based products.

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7. References

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Appendix

Aluminium Survey

Section 1.

Email: _____
Name of the participants: _____
Age: _____

Gender:
1) Male
2) Female
3) Prefer not to say
4) Other

Occupation:
1) Working
2) Not working

Education Qualification:
1) SSC
2) HSC
3) Diploma
4) Graduate
5) Postgraduate

Family Annual Income:
1) Below 1 lakh
2) Between 1to 5 lakh
3) Between 6 to 10 lakh
4) Above 10 lakh

State:
1) Maharashtra
2) Other

City: _____

Area:
1) Urban
2) Rural

Family:
1) Nuclear
2) Joint

Section 2. These questions may have more than one answers

1. The vessels which I use for cooking purpose are made up of
   1) Aluminium
   2) Stainless steel
   3) Hard anodized black vessels
   4) Glass
   5) Clay
   6) Non-stick vessel

2. I use aluminium vessel for
   1) Cooking vegetables
   2) Cooking pulses
   3) Boiling drinking water
   4) Making tomato chatney
   5) Rice
   6) I don't use aluminium vessels

3. I use aluminium foil
   1) To wrap chapatti in lunch
   2) To wrap uncooked food
   3) For baking purpose
   4) To wrap chapatti in lunch
   5) I don't use foil

4. The vessels which I use to stored cooked food are
   1) Aluminium
   2) Stainless steel
   3) Hard anodized black vessel
   4) Non stick
   5) Clay
   6) Glass
   7) Plastic

5. The reasons I prefer use of aluminium vessels are
   1) Easy availability
   2) Cheaper
   3) Cook food fast
   4) Easy to clean
   5) Easy to maintain
   6) Don't have aluminium vessel

Section 3. Likert Scale

1. I use aluminium cookware for cooking.
   1) 5 Always
   2) 4 often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

2. I use aluminium foil for wrapping food like chapatti/ bread/ salad.
   1) 5 Always
   2) 4 Often
   3) 3 sometimes
   4) 2 rarely
   5) 1 Never

3. I use aluminium foil for cooking and baking food.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

4. I leave the cooked food in aluminium vessel to be consumed later.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1. Never

5. I prefer aluminium vessels for cooking purposes over vessel of other metal.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

6. I think that the use of aluminium vessel for cooking purposes and other household usage is safe.
   1) 5 Always
   2) 4 Often

3) 3 Sometimes
4) 2 Rarely
5) 1 Never

7. I use steel wool to clean my utensils.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

8. I use baking powder and cake mix.
   1) 5 always
   2) 4 Often
   3) 3 sometimes
   4) 2 Rarely
   5) 1 Never

9. I use aluminium vessels to make tomato sauce/ soup.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

10. I use aluminium vessel to make basundi / condensed milk.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

11. I use aluminium vessel to make curd.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

12. I use aluminium cooker for cooking.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

13. Some people in my family have acidity and take antacids.
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

14. Some people in my family use antiperspirants (deodorants)
   1) 5 Always
   2) 4 Often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

15. Some people in my family use sunscreen
   1) 5 Always
   2) 4 often
   3) 3 Sometimes
   4) 2 Rarely
   5) 1 Never

16. The aluminium vessels in my home are.
   1) Very old
   2) Old
   3) New
   4) Old as well as new