Conclusions
Ingestion of aluminium by human beings has assumed significance due to recognition of direct or indirect implication of aluminium in Alzheimer’s and other related diseases. The present study has been directed to study the extent to which aluminium can be leached out from aluminium cooking vessels and may find way into human system through this route. Aluminium is also known to be complexed strongly with fluoride ions and it was therefore, considered that cooking medium with higher concentration of fluoride might accelerate leaching of aluminium from cookwares. In addition, aluminium content present in certain beverages and common food items has also been estimated and their ingestion pattern by human beings is also calculated.

Important conclusions that emerge from the study carried out on the abovementioned lines can be broadly divided into two main groups viz. conclusions pertaining to aluminium leaching and presence of aluminium in beverages and food items.

6.1 CONCLUSIONS PERTAINING TO ALUMINIUM LEACHING

6.1.1 On performing leaching studies using saucepans it was demonstrated that experiments using different types of saucepans available in the market did not not yield
reproducible results. This non reproducibility was attributed to the dependence of aluminium leaching on quality and make of aluminium as well as difference in shape in size and the surface characteristics of cooking vessel.

Experiments were then carried out using aluminium coupons (of same size and shape) made out of aluminium sheets that are used in manufacture of aluminium utensils.

Consecutive leaching of aluminium with one coupon (upto four times) in every condition again offered non-reproducible results probably on account of different types of electrochemical cells being formed on the surface of coupon after every leaching episode. More meaningful and systematic data emerged on taking the average of all the four consecutive leachings. That commercially available aluminium utensils would offer significant variation in leaching of aluminium under identical conditions on account of variation in oxidation of aluminium at the surface is an important observation of the study. Studies on aluminium leaching in presence of several organic acids with variation of fluoride concentration were also carried out as in Indian cooking these acids are normally present. Other conclusions drawn from the present study are briefly described below.

a) Both higher concentration of fluoride and lower pH when applied together, enhance aluminium leaching to a great
extent. It can also be safely concluded that at 10 ppm fluoride no appreciable aluminium was obtained when pH was kept between 4 and 8. Thus, boiling water or cooking food in near neutral medium does not enhance aluminium leaching from vessel even at elevated concentration of fluoride. Cooking at pH 3, 4 and 9 (acidic and alkaline medium respectively) with 10 ppm fluoride does not significantly enhances the aluminium leaching. The study on the successive use of coupon demonstrated very clearly that in most of the cases aluminium leaching reduces to almost negligible amount on the fourth usage of the coupon. This observation can help the consumer by way of information that rinsing of new aluminium utensil in acidic condition 3 - 4 times before putting it to actual use would lead to still lower exposure of aluminium.

b) Maximum content of aluminium concentration was found to be leached in case of oxalic acid at pH 2 while minimum aluminium was leached in the case distilled water and in pH 4 for oxalic and acetic acid. As pH of the acid is increased from pH 2 to pH 4 content of aluminium leached decreases in case of all the acids studied.

c) Maximum content of aluminium was found to have been leached at 10 ppm fluoride concentration while minimum aluminium was obtained in case of 0 ppm fluoride for all the conditions studied. Presence of fluoride alone, it appears, does not lead to leaching of aluminium in significant amount
as evident in case of distilled water, but presence of acid does accelerate the aluminium leaching significantly.

d) As far as leaching and ingestion of aluminium through cooking in aluminium vessel is concerned (in presence of any of the acid studied) the most important factor is pH of the medium. Large amount of aluminium gets leached out in acidic medium as well as in alkaline medium (pH 9) though magnitude of leaching is not as pronounced as in acidic medium. Since the cooking medium in the Indian context in general is either near neutral or of the order of pH 3 to pH 4 (for acidic cooking), amount of leached aluminium would mainly depend on the nature of the acid present. At these pH values tartaric acid is found to be least effective in leaching aluminium at all the fluoride concentrations (0 to 10 ppm). These observations leads one to conclude that variation of fluoride concentration from 0 to 10 ppm in the pH range 3 to 4 does not enhance aluminium leaching significantly. As a matter of fact, pH value and presence of organic acids are found to be more effective contributing factors in aluminium leaching.

e) On performing statistical analysis of the data it was observed that effective negative correlation existed between pH vs aluminium for all the acids while no correlation was found to exist between aluminium and fluoride in case of acetic, oxalic and tartaric acids and at pH 9. However,
significant correlation was observed between aluminium and fluoride in case of distilled water and citric acid.

f) Total ingestion pattern of aluminium (per 100 ml solution) obtained in leaching experiments ranged between 0.08 to 2.12 mg considering all the conditions studied for pH 3, 4 and 9 at fluoride concentration of 2 ppm.

g) Leaching of aluminium was found to be quite low in the presence of tartaric acid (a common ingredient of tamarind). On the other hand cooking with acetic, citric and oxalic acid for the same pH i.e. pH 3, leads to an 2 to 4 folds increase in the leaching of aluminium.

h) It can thus be concluded that acidic food prepared in aluminium vessel using tamarind would lead to leaching lesser amount of aluminium as compared to cooking in presence of lime or vinegar (citric and acetic acid respectively) assuming all other factors to be consistent.

6.2 CONCLUSIONS PERTAINING TO ESTIMATION OF ALUMINIUM IN BEVERAGES AND FOOD ITEMS

6.2.1 In food items the aluminium leaching in case of tea and coffee was found to be negligible and the amount obtained is mostly the aluminium already accumulated in tea leaves. Food items like baking powder contribute aluminium to great extent as compared to that in case of toothpaste and pan
masala. Toothpaste packed in aluminium tube offers more aluminium to the users as compared to toothpaste packed in plastic tube.

a) Ingestion of aluminium in case of tea ranged between 0.26 to 0.42 mg per cup (100 ml) in tea samples prepared in aluminium saucepans while in coffee samples ingestion per cup was found to be only 0.063 mg.

b) Ingestion of aluminium from toothpaste per brushing, considering 2 g toothpaste is used per brushing and 20 % of it ingested, ranged between 2.18 to 4.25 mg. The ingestion of aluminium through pan masala per sachet considering 5 g pan masala to be present in one sachet and 20 % of it ingested ranged between 1.17 to 1.89 mg and 1.99 to 2.10 mg in case of pan masala without tobbaco and with tobbaco, respectively. In case of baking powder where aluminium is one of the main ingredient, aluminium content was found to range between 16,425.0 to 33,825.0 ug/g. One teaspoonful of baking powder will therefore contain aluminium in the range of 82.12 to 169.12 mg.

It can thus be concluded that preparation of food stuffs in aluminium vessels using aqueous medium having fluoride concentrations upto 10 ppm is not hazardous from the point of view of excessive ingestion of aluminium through this route since mostly near neutral foods are prepared in aluminium
utensils and even cooking acidic food (pH between 3 to 4) for e.g. sambhar and rasam leads to leaching of negligible amount of aluminium. It is also noteworthy that much larger amount of aluminium is leached in first two leachates and the value of aluminium leached decreases with subsequent leachings i.e. with continuous use of cooking vessel.

Normal cooking recipes in the Indian context therefore, does not enhance aluminium exposure of human beings on cooking food in aluminium containers.