Recycled aluminium used in low cost shielding

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Abstract. The used high atomic weight and density materials, like lead and barite, contribute with the environmental problem, when they will be hand and disposal. Therefore we showed the recycled aluminiums possible as shielding material for mammography X ray. In addition to the environmental gain, we will have the social gain, since the aluminium used came from recycled. Attenuation measurements could made with recycled and high pure aluminium (99.999%), the results shows better than 1%.

1. Introduction
The human action has an environment impact that could be greater or lesser gravity, which ecological imbalance generates, that could be assimilated or even generates catastrophic changes. Concern with sustainable development is becoming inevitable, since world population increase, therefore forced increasing production and then consequent residues increase that are environment dispensed, which could generate an imbalance making life impossible on Earth as we know [1].

The 3 R's policies (reduce, reuse and recycle) is the most accepted as the best way to achieve sustainable development. Priorities hierarchy is exactly the order which it presents: we must reduce environment exploitation, as a priority; reuse what has been produced as long as possible and recycle what cannot be reused [2].

In this way we are concerned with the environmental impacts caused by used materials in the shielding of ionizing and electromagnetic radiation, which leads us to seek new ways of accomplishing them with the reuse of materials. The use change of the classic shielding material, leaving heavy metals manipulate with, whose environment exemption can cause serious damages [3]. In additional to fail use high environmental impact material, we think to be created a new way for used aluminium packaging, avoiding the inappropriate disposal of these packages in the environment.

Shielding in X ray services has been chosen because its peculiar characteristics and different examination types, whose X rays generation is projected in order to produce an image through low energy photons [4].

These reused material proposed brings an addition environmental gain advantage. As proposed to take advantage of used aluminium cans there will be added value to this material, created more one way to support for the excluded population society.

The recycled material should be flat and the new way of collecting should be used, creating a new business, the social inclusion through work is another indirect gain from this research [5].

The objective is demonstrated technically feasible to use aluminium, from recycled beverage cans, for X ray room shielding.
The attenuation factors, in the mammography energy range, of recycled aluminium foils, with several thicknesses, were compared to ones obtained by high pure (99,999 %) aluminium, used in calibration laboratories.

2. Ionizing radiation avoidance techniques

There are three effective ways to avoid ionizing radiations: time, distance and barrier. It should be kept as far as possible from the radiation source, time exposed shorted as possible and barrier interposed between the source and individual. Among these three forms the most effective is the distance [6].

Certain materials and its thicknesses shown that reduced the radiation effects. Using this principle to be used as X rays shielding, beginning to notice how higher denser and atomic number materials are block them and more effectively [7].

The better result material which has ease obtain a controlled thickness and which has an abundance that guarantees a reasonable price for X ray shielding is lead [8]. The wall shield can also be made by incorporating barite, a barium compound, which ensures the sealing and reduces costs [9].

The conventional shields, made with lead and barite, no longer take into account that X ray radiation is attenuated by interaction with different other materials. The conventional screening materials used could have some draw backs, both materials are heavy metals that environment pollute when their wastes are not properly disposed off, including since mining to disposal.

Each radiology service will require specific calculations for each wall barriers, on each screen, taking into account the photons energy to be shielded, the workload to be executed on site, the occupancy type behind the barrier and the shield material type used [4]. These calculations are indispensable not only for the radioprotection but also for the environmental view, since a precise calculation reduces the shield material use.

2.1. Aluminium material

It is the third most abundant element and nonferrous metal in the earth's crust, found in bauxite. Bauxite processing, which includes grinding, digestion, filtration, precipitation and calcination phases, produces the alumina, that becomes the primary aluminium. Followin the secondary aluminium is when obtained by processing aluminium scrap. One of the most important characteristics of aluminium is its ability to be infinitely reprocessed without losing its properties [10].

Aluminium is a light metal whose density is 2.7 g / cm³, whose melting point is 660 ° Celsius, non-toxic, with high thermal and electrical conductivity, impermeable and opaque, malleable and resistant to corrosion [11].

Due to its characteristics, it is widely used in the most diverse applications, from the aeronautical industry to the packaging of food, passing through the production of electricity conducting wires, combustion engine blocks, doors, windows, heat exchangers, vehicle chassis, thermal insulation and even in the treatment of water [10].

Aluminium is made by an electrolytic process that consumes very large amounts of electrical energy, about 15 MWh is consumed [10]. The aluminium recycled saves 95% of the energy needed for production, in comparison to bauxite processing. In addition to the large energy savings, five bauxite tons produce one ton of primary aluminium. The recycling process reduces the mining activity, that is environment harmful [12]. Brazil is the second largest bauxite producer and the sixth largest primary aluminium producer [10].

The aluminium recycle cans is considered as example, in 2008 it reached a Brazilian record, with 96.27% of the beverage cans returning to the production chain, as shown in Figure 1. In addition to the environmental implications, there are social implication as well, since about 150,000 workers live on aluminium cans recycling and their incomes are higher than the minimum wage [10].
Experimental set up

The used aluminium results from beverage cans collection by different brands [13]. The cans caps and bottoms were removed and their bodies opened to leave them in sheet form. The sheets were simply washed with soap and water to remove any beverage residues, the average thickness was measured with a micrometer, the mean value were found 0.1 mm per leaf. Measures were taken to ensure the uniformity for aluminium attenuation, with differences smaller than 4% between different leaf regions, Figure 2.

The high pure aluminium (99.999%) used for comparison was the same as used in the radiation beams implementation for calibration, where ten sheets of this aluminium with 0.1 mm thickness per sheet were used.

The ionization chamber reference was used, PTW model 23342, suitable for use in low energy X rays with 0.02 cm$^3$ sensitive volume, connected to the electrometer Keithley model 6517A. The X ray tube was the Panalytical with side window model PW 2185/00 with molybdenum anode, water cooling and beryllium window, without additional filtration.

How done

The ionization chamber was positioned and aligned to the tube window at 600 mm focus-chamber distance. The attenuators support was placed at 300mm from the tube, where large distance fader-chamber, which will serve to reduce the effects of measurement scattering. The central region of the aluminium sheets was aligned with the focus-chamber axis, according to experimental set up present in Figure 3.
The tube current and high voltage was set at 50 mA and 28 kV, respectively. Ten measurements were performed for each aluminium included at the additional filtration, without attenuator and with the addition of one to ten aluminium foil, both from cans and hyper pure aluminium filtrations.

4. Results
The measurements results, shown in Figure 4, indicate that the comparison between the high pure (99.999%) and the recycled aluminium has a 1 % maximum relative difference.

Since ten measurements of the attenuation factor were performed for each thickness for high pure (99.999%) and the recycled aluminium are shown the mean values and standard deviations at table 1.

![Figure 3](image3.png)

**Figure 3.** Set up used at de Brazilian Metrology Laboratory.

![Figure 4](image4.png)

**Figure 4:** Comparison of the attenuation factors achieved with high pure (99.999 %) and recycled aluminium[13].
Table 1: Mean values and standard deviations from ten measurements of the attenuation factor were performed for each thickness for high pure (99.999%) and the recycled aluminium.

| thickness | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| high pure (99.999%) aluminium | Mean (nC) | 0.3279 | 0.1432 | 0.0925 | 0.0682 | 0.0538 | 0.0437 | 0.0357 | 0.0298 | 0.0254 | 0.0222 |
| | SD | 0.0033 | 0.0004 | 0.0002 | 0.0006 | 0.0001 | 0.0002 | 0.0002 | 0.0001 | 0.0002 | 0.0002 |
| recycled aluminium | Mean (nC) | 0.3451 | 0.1561 | 0.0918 | 0.0688 | 0.0535 | 0.0433 | 0.0368 | 0.0310 | 0.0266 | 0.0240 |
| | SD | 0.0003 | 0.0002 | 0.0002 | 0.0003 | 0.0002 | 0.0002 | 0.0001 | 0.0001 | 0.0002 | 0.0001 |

5. Conclusion
The results confirm the possibility to use recycled aluminium material for X ray shielding.

The primary beam attenuation is already sufficient to confirm the research hypothesis and taking into account that the dispersed radiation energy is smaller than the primary radiation beam.

The focus-attenuator distance is the same as used by calibrations laboratory and shows the efficient as a attenuation material, that became as a shield wall.

The commercial alluminium used to produce the foils use at the can is not high purity as used at the calibrations laboratories, but the impurity into the foil shows the possibility material shield could be used.

The hypothesis confirmed in this research makes us seek deeper results that will be tested in different energies and field, producing a material prototype for shielding with the embedded finish.

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