Today's WASTE is Tomorrow's WEALTH: Recovery of Rare Earths from Waste Magnets of Wind Turbine

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The role of "METALS" in the development of human civilization is well-known. Metals are the solid material known for its malleability, ductility, electrical and thermal conductivity. Starting from agriculture to automobiles, computer to construction, electricity to equipment, mobile to medicine, s to spacecraft, television to transport and wires to weapons, metals in combination of other materials and alloys are used as an integral and essential part of modern technologies. Our every day life and its comfort cannot be imagined without the use of metals.

Among 118 elements discovered yet, there are few metals having special properties. The addition of small quantity of these metals can drastically change the quality or performance of the product. For the past decade, we have observed that fluorescent tubes/ CFLs/ LEDs have replaced lightbulbs for lighting in our homes. There are some important metal present inside the coating of fluorescent tubes, LEDs, etc., which produces bright white light. These special metals are known as "Rare Earth Metals". One fluorescent lamp contains only 1-2 gram of rare earth metals,but the presence of this small quantity drastically improves the lighting performance.

Have you ever thought about how data is stored in the hard disk of a laptop or computers? Hard disk contains one critical component i.e. "Rare Earth Magnet"which is responsible for

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storing and retrieving the digital information. In a hard disk, around 10-20 g of rare earth magnets is used for storing the digital information. These rare earth magnets are known as "Neodymium-Iron-Boron (NdFeB)" magnets. NdFeB magnets are also used in speakers, earphones, generators of wind turbines, motors, etc. In generators of wind turbines, around 250-650 Kg of NdFeB magnet is consumed to produce 1MW of electrical energy.Around 16% of the rare earth metals produced worldwide is utilized for the production of NdFeB magnets used in wind turbine.

NdFeB contains 23-27% of Neodymium (Nd), 63-67% Iron (Fe) and ~1% Boron (B). Neodymium is one of the important rare earth elements used as ingredient of magnet. The combination of Iron with Neodymium in NdFeB magnet generates superior magnetic properties. These magnets require 70-90 times lesser volume in comparison to conventional magnets (AlNiCo and Ferrite magnets) for producing the same magnetic strength. Therefore, the use of NdFeB magnet is continuously increasing in various applications to minimize the size and weight of the product. Currently, NdFeB magnet industry is developing with a growth rate of 20% per annum.

In recent times, Rare Earth Metals are like "Salt and Pepper" of modern technologies, due to their special chemical, magnetic and fluorescence properties. Rare Earth Metals are a group of 17 chemically similar elements (Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium and Lutetium). Rare earths are not actually "RARE" in nature. The word "rare" came from the difficulty experienced in separating the 17 rare earth metals from minerals. The first rare earth metal was discovered in 1787 and it took more than 100 years in identifying all rare earths as individuals due to their similar chemical properties.

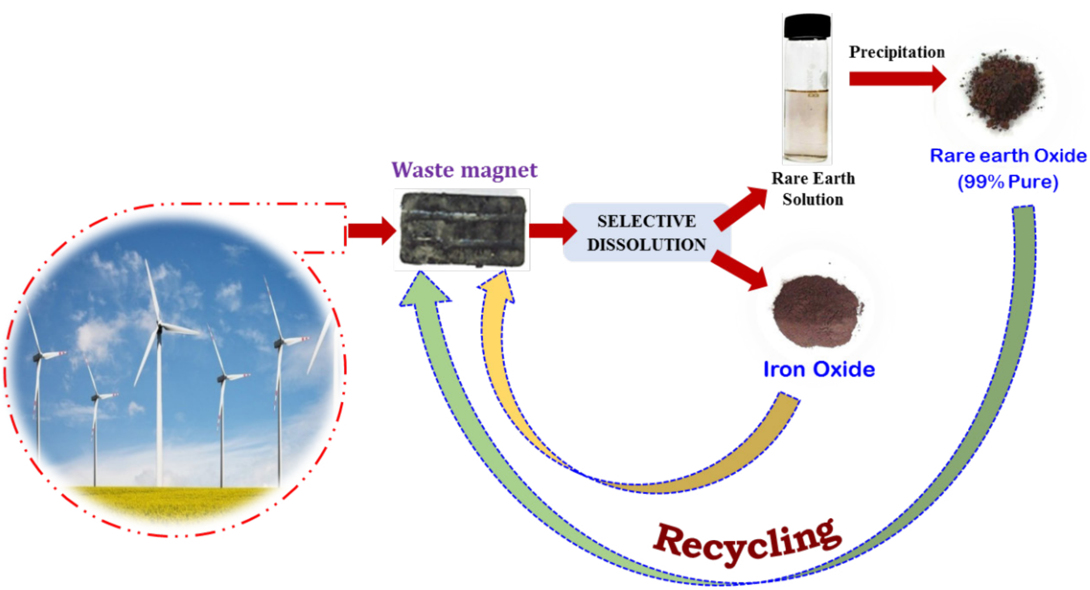
Due to growing application of rare earth metals in various applications, their global demand is increasing continuously. Currently, around 96% of rare earth metals are produced by China. Researchers around the world are striving to develop an indigenous process to recover valuable rare earths to fulfill their domestic demand. India has 3.4 million tons of rare earth reserves mainly available in beach sand. But, the processing of rare earths from primary ores involves mining and multiple process steps, leading to overburden and affecting the environment.

To address this situation, researchers at CSIR-National Metallurgical Laboratory have identified the "waste NdFeB magnets generated from the wind turbine industry" as potential source of rare earths. India has an ambitious plan to generate wind energy of 100GW by 2030. Therefore, the installation of wind turbines is continuously increasing in southern parts of the country. In wind turbines, strong magnetic field is required to convert the mechanical energy in to electrical energy. For this, NdFeB magnets in huge quantity (250-650 Kg for 1MW) are used in generators of wind turbines. After a certain year of life span, the magnet assembled in the generator loses its magnetic property due to continuous exposure to air or heating environment. These bulk quantities of discarded magnets can be utilized as secondary resource for the recovery of valuable rare earths.

The researcher at CSIR-NML obtained the waste magnets from Regen Powertech Pvt. Ltd., a leading wind turbine industry of India. They developed a simple process to recover rare earths from the waste magnets with minimum consumption of chemicals. Iron oxide is obtained as by-product of this process. The recovered rare earth oxide and iron oxide can be recycled for the preparation of fresh magnets and many other applications.

The received discarded magnet was in the form of rectangular blocks. The magnet was characterized in the laboratory to understand the property of material. It was found that the magnet was made of rare earths majorly Neodymium (23%) along with Praseodymium (5.6%) and Dysprosium (0.4%)) and iron (67%) in the form of $Nd_2Fe_{14}B$ alloy (homogeneous mixture of metals having single phase). A process was developed to selectively recover rare earths from $Nd_2Fe_{14}B$ phase. Firstly, the magnet block was heated at 310 °C in order to remove residual magnetism. Further, the magnet blocks were crushed and ground to obtain magnet powder of certain size range. The magnet powder was then heated in air inside a furnace at 850 °C. As a result, Rare Earths and Iron initially present in the metallic form are completely converted into Rare earth oxide (RE_2O_3)and Iron Oxide (Fe_2O_3).

The solubility of rare earth oxide is higher than iron oxide in acid solution; so this property is used for the preferential dissolution of rare earth oxide in solution. Hydrochloric acid is used for dissolution of oxidized magnet powder. Different parameters such as acid concentration, temperature, solid/liquid ratio and time are optimized in such a way that rare earths are selectively dissolved in aqueous solution with minimum consumption of acid. It is observed that for selective recovery of rare earths, selection of parameters during dissolution process is very critical; otherwise iron could also dissolve in solution as impurities. After dissolution, remaining solid is separated from the solution by filtration process. When the obtained solution is chemically analyzed, it is found that solution is rich in rare earths comprising Neodymium along with Praseodymium and Dysprosium. More than 98% of the rare earths is recovered in the solution with only 0.02% of iron impurities. These impurities are removed during further precipitation step.



Oxalic acid was added in rare earth rich solution for precipitation (to make the solid compound of rare earth). By heating of precipitates, brown colour oxide of rare earths (containing Neodymium, Praseodymium and Dysprosium) is obtained. The purity of produced rare earth oxide is ~99%. The solid residue obtained after filtration is the by-product of the developed process which is found in the form of Iron oxide (Fe_2O_3) of purity ~93%, which could have direct application in pigment industry. The process is developed in closed loop cycle, so no acidic/toxic effluents are generated. The result of the work was recently published in Waste Management Journal in 2018 led by Aarti Kumari, AcSIR, CSIR-NML, Jamshedpur. The research team constituted Aarti Kumari, M. K. Sinha, S. Pramanik and S. K. Sahu from CSIR-NML.

Overall, waste NdFeB magnet of wind turbines found as potential source for recovery of rare earth metals. A complete process flowsheet is developed at laboratory scale for recovery of valuable rare earth oxide along with iron oxide from waste NdFeB magnets with minimum consumption of acid. This indigenous process could be helpful to meet the domestic demand of rare earths in the country, which could lead to fulfilling the dreams of **"Making RARE EARTHS in INDIA"**.