The Hazards of Electric Car Batteries and Their Recycling

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Abstract—In recent years, under the double pressure of energy exhaustion and environmental deterioration, the development of electric vehicles has become the major development trend of the automotive industry in the future. This paper discusses the problem of abandoned batteries caused by the limited life of a large number of batteries with the prosperity of new energy vehicle industry. This paper lists and analyzes the different characteristics of batteries commonly used by three new energy vehicles in the market: (1) lead-acid batteries will not leak in the use process due to tight sealing, but their use cycle is very short. (2) The production of nickel metal hydride battery is relatively mature, its production cost is low, and compared with lithium electronic battery is safer. (3) Lithium-ion batteries are made of non-toxic materials, which makes them known as "green batteries". However, they are expensive to make and have poor compatibility with other batteries. Because discarded batteries pose a threat to human health and environmental sustainability, lithium-ion batteries may overheat and fire when exposed to high temperatures or when penetrated, releasing carbon monoxide and hydrogen cyanide that can be very harmful to human health. In addition, waste batteries will also cause water pollution and inhibit the growth and reproduction of aquatic organisms and other potential dangers. Therefore, it is necessary to recycle it efficiently. This paper then introduces the advantages of three recycling methods: step utilization and recovery, ultrasonic recovery and sodium ion battery. These recycling methods can maximize the reuse efficiency of waste batteries. This paper expects to find a better way to recycle waste batteries to solve the potential problems of improper disposal of waste batteries and reduce the environmental hazards of waste batteries.

1. Introduction
Under the trend of the global movement to cope with sudden changes in climate, in recent years, the electric vehicle market has been booming globally. Due to the frequent use of lithium-ion batteries to power electric vehicles, a large number of batteries will soon reach the end of their service life and be scrapped andpollute the environment. How to recycle them to reduce environmental pollution and promote the sustainable development of the electric vehicle market has become an urgent challenge today. This is a very valuable recycling strategy to implement the recycling of waste electric vehicle batteries. However, looking at the entire international market, the development potential of the electric vehicle market is huge. In the future, in order to achieve the global goal of reducing greenhouse gases, to improve the air quality in cities, and to meet the needs of consumers at the same time, the potential consumer base of electric vehicles in various countries is also expanding [1]. With the expansion of the tram market, the society's demand for batteries has also soared. In the global market, there are three types of batteries most commonly used in electric vehicles: lead-acid batteries, nickel-metal hydride...
batteries and lithium-ion batteries. Lithium batteries are widely used in electric vehicles on the market to provide electricity. The first lithium-ion batteries were invented at the end of the 20th century and were used to power automobiles in the early 2000s. In contrast, fuel vehicles have existed for more than 100 years, so relatively speaking, we have not yet obtained the same data and understanding in terms of product safety.

According to estimates, by 2025, 11 million tons of waste lithium-ion batteries will flood our market without a system to deal with them. If we are to deal with climate change, we must make full use of existing battery resources as much as possible to avoid pollution from toxic waste and ensure a strong supply of raw materials at low environmental costs. If discarded batteries cannot be effectively disposed of, it will cause huge damage to the environment and humans. When the battery is damaged, it will generate a lot of heat and cause a fire, and it will release incredibly toxic gas. In addition, to humans, waste batteries have many potential hazards, and high concentrations of lithium can cause great harm to the human nervous system and endocrine system.

The main purpose of this article is to analyze the hazards of electric vehicle batteries and recycling technologies. First, we briefly analyzed the advantages and disadvantages of electric vehicle batteries, and then we elaborated on the harm caused by electric batteries to the environment and humans, and introduced several common technologies for recycling electric batteries: cascade utilization and ultrasonic recycling technology. Finally, we mentioned the future of battery technology, sodium-ion batteries may be able to replace lithium batteries to reduce harm.

2. Batteries

2.1 Advantages of new energy vehicle batteries

2.1.1 Lead-acid battery
A battery whose electrode is mainly made of lead and oxide and whose electrolyte is sulfuric acid solution. The VRLA battery can be used for floating charge for 10-15 years due to its corrosion-resistant lead-calcium alloy plate. Because the gas compounding system is able to convert the generated gas into water and thus no water is required during the use of VRLA battery. Therefore, it is easy to maintain and clean the VRLA battery. Also, because lead-acid battery is securely sealed, during the use of them, the electrolyte won't leak out of the battery terminal or casing, and because there is no free, the battery can be placed anywhere [2].

2.1.2 NimH battery
NimH battery, the type of battery with good performance. Nickel-metal hydride batteries are divided into two different types: high-pressure nickel-metal hydride battery and low-pressure nickel-metal hydride battery. its positive active substance is Ni (OH)₂ and the negative active substance is metal hydride. Compared with lithium ion battery, nickel-metal hydride battery has more mature manufacturing technology, so its cost of production is relatively low and is more friendly to the environment. They usually have long service life. In terms of safety performance, nickel-metal hydride battery is safer than lithium ion battery due to its relatively low capacity density. In this way, it is prone to smoke explosion [3, 4].

2.1.3 Lithium ion battery
Lithium-ion battery is usually called the rechargeable battery. Its normal operation mainly relies on lithium ions moving between two electrodes, the negative one and positive one. The energy density of lithium-ion battery is high, and its volume energy density and mass energy density can reach 450 W. h/dm³ and 150 Wh/kg respectively, which is improving. At the same time, because petroleum coke and graphite as its anode materials are non-toxic and abundant, the absence of toxic and harmful substances let lithium ion batteries called green batteries. In addition, the lithium ion battery can be charged and discharged for more than 900 times under the 100% DOD. When using shallow depth (30% DOD)
charge and discharge, the number of cycles of the battery has exceeded 5000 times. That's why its service life is relatively long [5].

2.2 Disadvantages of batteries of new energy vehicles

Through the analysis of Table 1 of "Characteristics of four different Batteries", different types of batteries have different defects. For example, lead-acid batteries have low specific energy and short service life. In order to ensure their safe and efficient operation, frequent daily maintenance is required. Nickel-metal hydride batteries are more expensive and less safe than lead-acid batteries. Then about the lithium-ion battery. Due to the high price of LiC002 cathode material used by this kind of battery, in order to prevent overcharge or over discharge, this battery must have special protection circuit, which leads to its high production cost. In addition, lithium ion batteries can only be replaced by three ordinary batteries (3.6 V), so the compatibility between lithium ion batteries and ordinary batteries is poor [6].

| Battery          | Negative electrode | Positive electrode | Electrolyte | Nominal voltage | Theoretical specific energy (Wh/kg) | Practical specific energy | Practical energy density | Major problems                  |
|------------------|--------------------|--------------------|-------------|-----------------|-------------------------------------|-------------------------|-------------------------|---------------------------------|
| Lead-acid        | Pb                 | PbO₂               | H₂SO₄       | 2               | 252                                 | 35                      | 70                      | Heavy, Low cycle life, Toxic material Cost, High pressure Hydrogen, Bulky |
| Nickel-hydrogen  | H₂                 | NiOOH              | KOH         | 1.2             | 434                                 | 55                      | 60                      | Cost, Pressure, Bulky, Safety issues, calendar life, cost               |
| Nickel-metal Hydride | MH             | NiOOH              | KOH         | 1.2             | 278-800 (depends on MH)             | 70                      | 170                     |                                |
| Lithium-ion      | Li                 | LixCoO₂            | PCor DMC w/LiPF₆ | 4               | 766                                 | 120                     | 200                     | Safety issues, calendar life, cost                                      |

2.3 Battery hazards

2.3.1 Damage to the environment

Fundamentally speaking, electric vehicles are extremely safe, but the potential problem occurs when they have been damaged, since exposing to extreme high temperatures or something pierces the battery wall, the battery will be extremely dangerous. Since lots of energy were stored in a very small space in battery, this energy will try to release it. So if the battery is exposed to overheating, or when the battery case has penetrating power, the battery will short-circuit internally. This short circuit will cause the so-called Joule heating, that is, heat is generated when electricity is passed through, and the battery cannot get rid of the heat as quickly as it generates heat. Finally, this heat will trigger a chemical reaction that generates more heat, forming a vicious circle. This is a process known as thermal runaway, and it can cause fires and, in some cases, even explosions. Although the data shows that fires caused by battery explosions are rare, it does not mean that this kind of possibility does not exist. Once this kind of disaster occurs, it will cause great harm. During an electric vehicle fire, more than 100 chemicals are produced, including some incredibly noxious gases such as carbon monoxide and hydrogen cyanide-both of which are deadly to humans and the environment. Moreover, the transportation of electric vehicles will also cause global air pollution and affect the environment. For example, acidification and eutrophication,
photochemical air pollution or adverse effects on human health, such as cytotoxicity, damage to genetic material, oxidative stress, or allergies (PM10, SO2, and NOx). Regarding the emission of pollutants PM10, SO2 and NOx, the environmental burden caused by electric vehicle transportation is higher than that of internal combustion engine vehicle transportation. However, the chemical emissions generated by vehicle transportation, especially lithium-ion batteries, have been ubiquitous in cities with high population densities.

2.3.2 Damage to the organism
NOx emissions from ICEV are prevalent in operation and therefore have a high potential hazard to human health. Lithium may cause considerable damage to the terrestrial and aquatic environment at higher levels [7]. For example, low doses of lithium have a significant inhibitory effect on the proliferation and growth of aquatic organisms, including Pimephales Promelas, Ceriodaphnia and Eliodaphia and Elmie Clavaeformis [8]. In addition, lithium in water will accumulate in plants, causing damage to plant growth and development [9, 10]. For example, 60 mmol/l of lithium can disrupt the growth of sunflowers; The same concentration will also affect the growth of corn [9]. Food chain can enrich lithium in animals, and high concentration of lithium will also cause serious damage to animals [11]. For example, rats were treated with low doses of lithium every other day for 7 weeks [12]. The epithelial intima of renal tissue was damaged, and some significant changes were observed in the cortical cartilage area and glomerular area. In addition, high concentrations of lithium can cause serious damage to humans, including nervous system (including chills and hyperreflexes), kidney (including sodium loss of nephritis and nephrotic syndrome), and endocrine system (including hypothyroidism) [13-16].

3. Technology for recycling batteries
Implementing secondary reuse of used electric vehicle batteries is a valuable recycling strategy. As the case of cars shows, the negative impact of batteries on the environment decreases with longer battery life. Car batteries can be reused in different industries, doubling the battery life cycle to about 20 years. When electric cars batteries fall below 70-80% capacity after about 10 years of use, they are no longer powerful enough to power a car. Therefore, there will be a large number of used batteries abandoned, in order to prevent the negative impact of these batteries on the environment and human beings, people began to adopt some means to recycle and reuse the waste batteries.

3.1 Cascade utilization and recycling
According to the degree of obsolescence, power battery recycling can be divided into cascade utilization and recycling. After the decommissioning of new energy vehicle power batteries, although they no longer meet the performance requirements of new energy sources, about 70% of the vehicle’s capacity can still be used in fields such as energy storage, photovoltaic power generation, low- and high-speed electric vehicles, that is, cascade utilization. Ladder utilization is mildly scrapped and can be used for secondary utilization of energy storage equipment and low-speed electric vehicles, such as the retired lithium iron phosphate battery in the field of communication base stations. Recycling is severely scrapped. It uses chemical methods to extract precious metal electrode materials such as lithium and cobalt for the purpose of material remanufacturing. Batteries are generally phased in when their performance drops to half or less of their original performance. As shown in Fig. 1, the process of disposing of used batteries is: recycling→detection and sorting→classification. After the waste batteries are screened, disassembled, and reorganized, they are affixed with step-by-step labels. These recycled batteries can be used in energy storage systems, street lights, and environmental protection. In order to get full use of energy, realizes the comprehensive utilization of the full life of power batteries, and infinitely expands the secondary utilization value of waste power batteries, the cascade utilization is considered to be one of the most remarkable ways.
3.2 Ultrasonic recovery

Ultrasonic recovery is a quick and easy way to use high-power ultrasound to remove active materials from composite electrodes in a continuous flow process, enabling the electrode to delaminate within a few seconds. Low-power ultrasound (<1000 W) has been used for cleaning, mixing and accelerating chemical processes. In lithium battery recycling, low-power ultrasonic vibration has been used to assist the electrode layering process. Fig. 2 shows the ultrasonic electrode layering technology. Fig. 2a shows the effects of cavitation and sound pressure in the de-ionized water lithium ion battery anode delamination process. These images were taken with a high speed camera (20 k frames per second). After 0.2 seconds, the graphite coating can be seen (Fig. 2b). First, it protrudes from the copper current collector, and then due to the cavitation of the coating and the copper foil interface generated by the pressure wave, the graphite coating will peel off into flakes. This delamination material is finally crushed after only 0.5 seconds, mainly through the effect of cavitation (Fig. 2c). Ultrasonic delamination technology effectively blows up the active material extracted from the electrode, leaving primary aluminum or copper. Facts have proved that this process is very effective in removing graphite and nickel manganese cobalt oxide (commonly known as NMC) [17].
Fig. 2 Snapshots taken by a high-speed camera during the ultrasonic layering process of electrodes: (a) 0.01 seconds after power-on; (b) 0.2 seconds after power-on; (c) 0.5 seconds after power-on. The ultrasonic generator (marked by the dotted line) has a diameter of 20 mm, a power intensity of 120 W cm\(^{-2}\), and a distance of 5 mm from the substrate. The solvent is deionized water [17].

3.3 The future of battery technology -- sodium ion batteries

SIB is considered the best candidate power source because sodium is widely available and its chemical composition is similar to LIB; therefore, SIB is a promising next-generation alternative. As a solid-state battery, the sodium-ion battery (SIB) works in roughly the same way as the lithium-ion unit and has similar recyclability. Sodium is cheaper and much more abundant than lithium, and SIB can reach the same level of performance as lithium-ion batteries (LIB). They are much less flammable than current LIBs and may even be more efficient. Despite the scalability of LIB, the geological problem that lithium resources are mainly concentrated in South America is considered a serious problem that needs to be solved. Academia and industry have recently issued warnings about this situation and expressed the need to use alternative rechargeable batteries that can substantially replace existing LIBs. In fact, sodium ion battery (SIB) was developed together with LIB in the 1980s; however, the poor battery performance of SIB compared to LIB is the main reason for the decline of SIB. The recent upsurge of electric vehicles and energy storage using LIB as an energy source may cause the shortage of LIB, the development of inexpensive sodium and uniformly distributed SIB has once again received widespread attention. Some of the advantages of SIB and LIB are as follows: (1) The possibility of high-performance electrode materials, because compared with lithium compounds, sodium transition metal compounds are relatively abundant; (2) the rapid diffusion of sodium ions in the solid phase, which indicates the advantages of Na batteries—the high rate performance; (3) Because the anode uses aluminum foil to replace the copper current collector and the LIB production line is transferred to the SIB that does not require new production facilities, the manufacturing cost is reduced [18]. SIB technology is a very important and promising follow-up technology of LIB technology. Due to the geographical distribution of sodium compared to lithium, the significance of SIB is cost-effectiveness. Therefore, in the long run, sodium ion batteries will replace or replace lithium ion batteries in the medium and large battery market. However, SIB still faces some challenges in developing optimized electrode materials and electrolytes.
with stable sodium storage capacity. So far, although some efforts have been made to find new electrode materials for SIB, much less research has been done on the electrolyte itself [19].

4. Conclusion
With the development of electric vehicles, the impact of waste electric batteries on us has become more obvious. Efficient battery recycling technology can effectively reduce the environmental and human health threats caused by waste batteries. The full text discusses the advantages and disadvantages of the three common electric vehicle batteries on the market, as well as their negative effects, and three common high-efficiency methods for recycling waste batteries. In terms of the environment, improper handling of waste batteries may cause fires, and the high temperature and toxic gas emissions will cause certain harm to the environment. Secondly, discarded batteries may cause acidification and eutrophication of water bodies, cause photochemical air pollution, and inhibit the growth and reproduction of organisms. Therefore, effective recycling of electric vehicles is very necessary. The recycling technology of electric vehicle batteries is also very impressive. The cascade utilization realizes the comprehensive utilization of the full life of power batteries, maximizing the use value and economic benefits of retired electric batteries. Ultrasonic delamination recovery technology can effectively separate valuable materials. Sodium-ion batteries can also replace lithium-ion batteries at a very low cost, but research on handling the electrolyte itself still requires effort. Despite some difficulties, electric battery recycling technology still has a lot of room for development.

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