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Viewpoint

Concerns to Be Considered during Recycling Operations

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Abstract: Recycling should in principle be the goal in all aspects of society. There are, however, limitations, as any recycling task may lead to pollution in the ground, water or air. In the most extreme case, recycling may lead to threats to human life. In this paper, we take examples from key industries where recycling can be harmful and where closed and sealed dumps should have been used, rather than the attempt to recycle such as the oil and gas industry, the construction industry and farming. Reuse, hereby defined as use for another purpose without industrial processes, will be briefly discussed. The objectives of the paper are to remind key industries about their responsibility to recycle in a manner that does not harm the environment and to promote recycling in a sustainable way. It is suggested that a recommendation to key industries be made, to carefully assess all consequences of recycling could enhance the recycling industry's contribution to a cleaner world. The paper is intended to serve as a reminder that recycling in all industries requires careful planning and engineering to represent a valuable contribution towards a sustainable society.

Keywords: reuse; recycling; toxic waste; pollution; unsafe recycling; sustainability

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1. Introduction

We will start the discussion by looking at reuse. In most societies, reuse is part of the normal economy, where products not considered for continuous use are reused by others or for new purposes. The best example is the use of clothes by several children in a family when the children are growing and the younger child could use the clothes, which no longer fit the elder brothers/sisters. However, even such obvious reuse should be handled with care; shoes are fitted to the users' feet and may cause problems when used by others. There is a large used-clothes market in all countries, even in high-income economies. However, used clothing could transfer illnesses if the clothes are not washed or cleaned. In the past, clothes from persons carrying tuberculosis were burnt. For the same reason, even books were burnt in the past and warnings were issued against using libraries, due to the potential for contracting deadly deceases.

There is a huge difference between reuse and recycling, in that recycling requires industrial processes to create new products from products we no longer need or from waste. Recycling could also involve burning to obtain energy and heat. During these processes, the outcome could be that toxic waste is created or that a poisonous product is produced.

A recent report [1] documents that some consumer products, including toys, made from recycled electronic waste are contaminated with toxic chemicals. The prospect of poisoning your own children when buying toys represents the ultimate worry for parents. This happens, despite strict laws on the importation of toys [2]. The concern calls for strict enforcement of present laws and regulations.

Very careful management of the recycling process is required to avoid situations where recycling creates toxic products or toxic waste, as shortcuts may give rise to large economic benefits, strict laws and a requirement for law enforcement. As an example, in cold countries, heating is required to keep up the temperature in-house. However, it is now becoming forbidden in parts of Norway to use older stoves for burning wood, due to their polluting effects [3]. It should also be noted that many people burn waste in the stove, increasing the polluting effect. Even London is struggling with pollution caused by wood burning [4]. The solution in Bergen is to allow only clean burning stoves produced after 1998 [3].

2. Recycling in Different Industries

2.1. The Nuclear Industry

The nuclear industry has, as a by-product, nuclear waste. Storage of this waste causes large problems, due to the damage potential and the long half-life of the waste. Recycling of nuclear waste represents a benefit, as typical reactors only extract a few percent of the energy in their fuel, and the amount of nuclear waste to store is reduced. Some countries recycle the nuclear waste, while others are hesitant [5]. However, recycling also creates new concerns and may not be economical using today's technology [6]. As a potential solution, the use of radioactive material with a shorter half-life, such as Thorium, is considered by many [7,8].

2.2. The Construction Industry

The construction industry generates millions of tons of waste annually. Recycling is part of the industry with considerable attention paid to energy efficiency and cost savings. Concrete represents the most attractive example [9], with crushing of the concrete and use of the crushed material as aggregate or fill [10]. Prior to this use, reinforcing steel has been reclaimed through the crushing process. In case the new concrete does not have a very high compression strength, other materials may also be recycled as part of the new concrete. This applies, for example, to glass fiber reinforced plastic [11]. In this respect, it should be noted that the production of cement for the concrete industry is a very energy-consuming process. Could we see the recycling of cement in the future through fine crushing of the concrete?

Steel is normally recycled through the scrapping of iron and the preparation of new steel products. The process requires considerable heat, and toxic substances are destroyed, although painted steel may contain very toxic paint cover, necessitating checks that toxic fumes are not released into the environment through the recycling process.

The construction industry also moves huge volumes of gravel, crushed rock and mud annually. The recycling of used ground material is quite problematic, as contaminated ground cannot be used as fill for new industrial plants but must be treated as special waste. Those large volumes of contaminated ground may be very difficult and expensive to treat and replace. Run-off into lakes, rivers and the sea will be poisonous to living animals and to persons coming into contact with the run-off. Of particular concern is the rehabilitation of the locations used for oil refineries, gasoline stations and chemical plants. Where run-off is not possible, special dumps must be utilized.

Some construction materials represent a danger to personnel and the environment. Asbestos was used in the recent past for insulation and for fire resistance. With the knowledge that asbestos is a key driver of asbestosis (leading to lung cancer), asbestos is banned from all construction-related projects. No recycling is possible, and the workers involved in the decommissioning of buildings with asbestos must wear special protective clothing. Also, Eternit, a construction material that is a mixture of asbestos and cement (in ratio 1:9) is a toxic waste and must be treated as such. The material was much used in the past for roofs and in piping. For waste handling, see References [12,13].

Finally, all non-recyclable construction materials end up on the dump. The run-off from dumps is of concern. Also, a dump often holds organic materials that rot and give off methane and other gases. The methane seeps through the overburden into the atmosphere and acts as a strong climate-heating gas. It is possible and should perhaps be mandatory for this gas to be collected for energy generation. The waste products from burning the methane are much less of a climate driver than the methane itself, as the methane is more than 25 times more efficient as a climate driver. The economy of tapping methane from the city dump must be assessed and the costs of methane emission to the atmosphere must be included in the economic calculations. For a discussion of landfill gas, see the United States Environmental Protection Agency's (EPA's) homepage on the Landfill Methane Outreach Program (LMOP) [14].

2.3. Farming

Farmers are specialists in recycling, as they dispose of manure and urine from animals. The technology for saving the nitrogen in the manure and urine has been much improved during recent years with the introduction of equipment that forces the fluid into the ground under pressure (Figure 1). Through this method, which is very efficient, though expensive, climate gas emissions are reduced and the smell (which is irritating for dwellers) becomes of less concern. For a discussion of the benefits, see Reference [15].

Figure 1. Modern equipment for spreading/molding down of manure and animal urine.

It could be asked whether the excrement from humans could be recycled back to the farms in similar ways. We should, however, warn about the disease-spreading potential of such recycling. Human waste is, in modern societies, collected in a suitable sanitary way to avoid the spread of disease. Thereafter, the waste product is brought back as soil for use in food production.

Farmers are exposed to industries that claim that sludge waste from their processes represents soil-improving potential. There is a good reason for farmers to be skeptical, as sludge could contain heavy metals or toxic waste, making their soil unsuitable for any food production. Likewise, farmers are met by industries claiming that landfill will improve the mechanization of their farmland. There are very good reasons to be skeptical, carefully assessing the potential for run-off of heavy metals to rivers or the pollution of groundwater sources [16–18]. In the case of problems, the farmer might be fined and would have to restore the land to the status quo.

In the near future, it is expected that micro plastics will be of very great concern. Sludge from waste claimed to represent an improvement to soils contains much microplastic. The authorities have been concerned with the amount of heavy metals in this sludge; however, the amount of plastic has not been regulated [19]. Of great concern is that the effect of such plastics on the human body is unknown, as is how the plastics are transferred through the food chain (vegetables, meat, milk, etc.). The ability of the plastics to carry viruses, diseases and antibiotic-resistant bacteria represents a potential large health effect. It is possible that all fields shall be required to be free from plastics. The author has seen farm fields (in northern China) nearly fully covered by plastic waste, which will neither rot nor be destroyed but will eventually be dismantled into plastic molecules. For a discussion of the final fate of plastics, see Reference [20].

2.4. The Oil and Gas Industry

There is a reason to distinguish support structures and production equipment when it comes to the recycling of oil and gas industry equipment, the reason being that production equipment has been in contact with hydrocarbons and may, therefore, contain toxic waste.

Support structures for the oil and gas industry comprise the steel space frame structures, the concrete platforms, the floating rigs and the ship-shaped floating vessels. There should not be a problem in recycling the steel. For steel that has been located in the sea, however, marine growth such as mussels and shells rot when the platforms are taken to shore, where the smell is revolting for neighbors and workers. Furthermore, the rotten material must be treated as special waste. Platforms are brought from offshore directly to the decommissioning yards.

The OSPAR Convention (The Convention for the Protection of the Marine Environment of the North-East Atlantic) [21] regulates the removal of offshore oil and gas support structures. All steel support structures must, in principle, be removed; only the platform fixed to the bottom, weighing more than 10,000 tons, may be left in place after the removal of topsides and the upper part of the jackets. Concrete platforms may be left at the location, provided topsides are removed and the platform cleaned of all remaining oil and toxic substances.

The production equipment comprises all well-related equipment, topsides deck equipment, storage tanks and subsea equipment that has been in contact with hydrocarbons. The production equipment contains traces of hydrocarbons, asbestos, radioactive waste, mercury, etc., all of which are toxic. The emission of fumes to the air through cutting by welding machines takes place, and run-off to water occurs when there is rain. It is possible that the toxic and polluting water killed the fish fry in a nearby fish farm that had to close its operations [22]. It is claimed in Reference [22] that: "If all the abandonment of installations from the North Sea was done indoors in a large workshop, one would be in control of all environmentally harmful emissions".

It should finally be mentioned that the reuse of oil and gas equipment is very challenging, due to considerable wear and tear on the equipment. Gazprom Neft reused some production equipment from Hutton TLP platform for their Prirazlomnoye production platform in the Pechora Sea. The reports (only orally) tell about problems with quality, wear and tear. It is not considered good practice to reuse older worn equipment in high-pressure industries like the oil and gas industry.

2.5. Ship Breaking

Ship breaking is an industry, which employs many people worldwide. Most of the ships are broken on beaches, as the ships are run onto the beach at high tide and then dismantled manually. This is very efficient when it comes to the recycling of materials, however, it is a workplace that is tremendously dangerous for the workers. Safety measures, with respect to handling toxic waste (for example asbestos), are basically absent, and the handling of the heavy steel plates is without protection. Even if laws on the prevention of risk in the workplace are in force in many countries, such laws are not referred to in many countries where the beach breaking of ships takes place. In Bangladesh, beach ship breaking accounts for one-fifth of all steel used in the country [23], see also Figure 2. In shipyards, the breaking of ships can be done safely, however, there may still be workers exposed to dangerous situations when working to recycle materials from older ships.

Figure 2. Ship breaking on a beach in Bangladesh [23].

The situation for the decommissioning and removal of wrecks may be different, as wrecks have to be broken at the site in case it is impossible to remove them. In Norway, we were reminded of the Biblical verse: "They shall beat their swords into plowshares" [24], when the steel plates of the warship Tirpitz were made into very powerful ploughshares [25] (Figure 3), in the years after World War II.

Figure 3. Ploughshare made from steel plates of WWII warship Tirpitz. Inventor: R. Skjærpe, an ingenious entrepreneur living in Jæren, Norway. Picture from 1951 [25].

2.6. The Electronics and Electric Car Industries

Rare earth elements are vital to the electronics industry [26]. It is, therefore, of key importance that the rare earth elements are recycled. Furthermore, the availability of these elements is not abundant, and there may not be sufficient to fulfil the demand of the world market. However, the recycling of electronics is cumbersome, and the technology for the easy breaking of electronics after use is not readily available. Manual workers could be exposed to toxic materials, using processes that do not protect them from toxic fumes, and robots should handle the recycling of electronic components.

The new electric car industry is dependent on the availability of rare metals such as lithium [27]. With the potentially exponential growth of electric cars, as requested by several governments, the availability of these materials may not be sufficient to cover demand. New processes based on materials that are more readily available are being studied; however, there is no doubt that recycling must be introduced to ensure the availability of the rare raw materials. The recycling processes must be safe for workers, and emission to air and water must not take place. The final recycling accounting spreadsheet for electric cars must be available to the public. The following must be included: The manufacturing process, including the mining of the rare materials for the production of batteries; the electricity generation (which should not include energy from coal-fired electricity generation plants); the wear and tear on the roads from the heavier electric cars; and the recycling process for the rare elements used in the batteries.

3. Conclusions

The availability of raw materials is limited; therefore, the recycling of used materials, equipment and production facilities will limit the shortage of minerals and raw materials. All equipment must, however, be decommissioned in an orderly manner, to avoid toxic emissions causing pollution to spread to air, water, land and, ultimately, into the food system. We are thus, faced with the task of identifying the most appropriate ways to recycle the parts that can be recycled and finding places to store toxic waste that cannot be used for other purposes. Burning in an orderly manner at high temperatures [28–30] may in some cases be the best solution, thereby also producing energy for heating and industrial processes.

The best solution to reduce the exploitation of raw materials will, however, in most cases, be to recycle the materials. The industry involved in recycling has, however, to be aware of the potential of toxic emissions and dangerous non-safe industrial processes. For some industries handling particular toxic materials with high pollution effects, strict regulations must be in place to avoid the good (the idea of recycling) ending up being bad (causing irreparable harm to people and to the environment). Careful management of recycling operations is, therefore, called for.

The main contribution of this paper has been to give a systematic review of the best recycling practices in some key industries and to call for methods and processes that will limit the emission of pollution. Most often, the scientific literature dives into analyzing specialized questions; therefore, a holistic summary of the concerns is contributed.

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