Pressure waves, shock waves and cavitation. Avant-garde techniques for the transformation of pollutants: the Italian contribution.

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Abstract

Chemical pollutants are foreign substances to the biological processes of living organisms. A polluted environment negatively affects the health of living beings, especially the reproductive system and spermatogenesis. Today, thanks to advanced technology in the field of nuclear physics we can equip ourselves with machines that help us solve, at least in part, the problem of pollutants. Thanks to them, a different concept of waste begins to emerge, which is no longer seen as a disposal expense but as a resource of raw materials, overcoming the concept of recycling. It all began in 1934, in Rome, when for the first time the nuclear energy was released by Enrico Fermi. The element radioactive uranium was used, but at the time the process underlying the release of energy was not recognized; it was the splitting of the uranium nucleus by means of neutrons. However there was the problem of critical mass; the Germans used pressure to get around it and they aimed to generate a shock wave inside any amount of uranium, starting from a pressure wave. Diebner, Gerlach and Trinks were the scientists who pioneered the method, but the advent of the Great War interrupted their work and the data were lost. In 1989, Metcalf surprised the scientific world with the discovery of sonoluminescence; in fact, it was not expected that sound and ultrasound could induce water to emit light. Subsequently, the first (1992-1998) and second (1999-2002) model of the US machine were invented, they were the first attempts to carry out nuclear reactions through cavitation. Respecting the tradition of classical culture, studies concerning piezo-nuclear reactions also began in Italy. The experimental results were preceded by theoretical studies which mainly involved scientific institutions and some Italian universities. The design of the ultrasound machine (cavitator) was developed by Professor Cardone in 2005. Thanks to Italian scientists, it is now possible to transform matter quickly through ultrasound, even toxic elements.
Conclusions: in the light of modern technology, we can believe that the metamorphosis of matter could be the main phenomenon for the de-pollution of liquids. Toxic chemical compounds can also be transformed into elements useful for industrial purposes.

Introduction

A polluted environment has significant repercussions on the health of living beings. Chemical pollutants are foreign substances to human biological processes and they can cause serious health effects in exposed living organisms, including cancer. The environmental contaminants are generally grouped into the following functional classes: dioxins, phthalates, per-fluorinated compounds, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), brominated flame retardants, heavy metals; last, but not least the estrogen analogues. In general, these toxicants are directly released into environmental matrices such as air, soil and water (S. Manzetti et al., 2014; A. Lazartigues, et al., 2013).
What is most worrying is the negative impact of pollutants on the reproductive system and the sexual sphere (P.A. Thompson, et al., 2015; S. Chen, et al., 2014). In fact, many of these environmental pollutants expose living organisms, including humans, to alterations in the reproductive processes that can make these organisms sterile. These are alterations that, under certain conditions, can be passed on to subsequent generations. Recent studies on the quality of human male sperm have shown that the main cause of the observed defects in male reproductive function is exposure to environmental contaminants rather than genetic defects (N.E. Skakkebaek, et al., 2016; H.A. Jeng, 2014; R.S. Tavares, et al., 2016).
The purpose of this article is to prove that these toxins, with current technology, can be made less dangerous or even transformed into useful substances. An example is heavy metals, harmful to the

health of living organisms, and also implicated in reproductive disorders. For this reason, the study of the mechanisms of impairment of fertility induced by heavy metals at epigenetic and biochemical level is important. Particularly toxic are cadmium (Cd), mercury (Hg) and lead (Pb). Although chemically classified as a metalloid, arsenic (As), which is also toxic, is often included in the group of heavy metals. The main global sources of anthropogenic contamination from heavy metals include several industrial processes, including the energy industry, transport, municipal waste management, illegal landfills, soil fertilizer wastes and fertilizers themselves (Piotr Rzymski et al., 2015; Peter Massányi, et al., 2020). Heavy metals, pesticides, herbicides, flame retardants and many other pollutants also have negative repercussions on spermatogenesis. It should be noted that males are more sensitive to this type of damage than females. The formation of mature sperm from spermatogonial stem cells (SSC) takes place in the testis, in a well-regulated microenvironment.

The perytubular myeloid cells and Sertoli cells present in seminiferous tubules form the basement membrane which along with cytokines, growth factors and blood vessels form the niche that supports SSCs (M.C. Hofmann 2008; J.M. Oatley, et al., 2012).

The follicle-stimulating action of the hormone (FSH), testosterone, estradiol and their tight regulation by the Leydig and Sertoli cells are essential for spermatogenesis. FSH and testosterone are hormones that exert their action on Sertoli cells and contribute to the development of germ cells (P.J. O'Shaughnessy, et al., 2010; A.K. Chowdhury, 1979). The effects of some environmental chemical contaminants cause damage to Sertoli cells, mainly through the induction of oxidative stress and apoptosis (Ramos-Treviño, J. et al., 2018; Premendu Prakash Mathur, Shereen Cynthia D'Cruz 2011). Today, thanks to advanced technology in the field of Nuclear Physics, we can equip ourselves with machines that help us solve, at least in part, the problem of pollutants. Thanks to these machines, a different concept of waste begins to emerge, which is no longer seen as a disposal expense but as a resource of raw materials, overcoming the concept of recycling.

Historical retrospective

Nuclear energy was first released in Rome, in October 1934, by Enrico Fermi. In that case, the radioactive uranium element was used, but at the time the process underlying the release of energy was not recognized; it was the splitting of the uranium nucleus by means of neutrons. It was the time when physicists were convinced that the nucleus of any atom could not be broken, nor split to release energy. It was a dogma born in 1919, when Rutherford, the discoverer of the nucleus of the atom, had ruled that it would always be a waste and not a source of energy for humanity.

Fermi turned to Rutherford and Bohr to ask for confirmation on his experimental hypotheses, but he got no answer from the first; while the second, with his twisted judgments, increased Fermi's confusion and uncertainty (Cardone F. 2016). It should be noted that Fermi had obtained these results by pure chance, from some buckets full of water that the cleaner of the laboratory hid under the table of the laboratory, table on which Bruno Pontecorvo worked. It was the water that had a dual function: it made it possible to identify, without unnecessary and lengthy tests, what was the most suitable substance for braking neutrons. In addition, the use of water helped to remove the prejudice regarding the actual role of these neutrons, recognizing only those slowed down the ability to induce radioactivity in a sensitive way. The variable that was sought, necessary to ensure the repeatability of experiments, was - metaphorically - hidden by chance under the table. Pontecorvo for this type of experiments used small silver cylinders whose radioactivity changed without apparent reason at any moment, but it took time to realize that the radioactivity induced in silver varied depending on whether the bucket was filled with water or empty. The experiments were repeated, with success, in a large tub in the garden where the neutron source and the silver cylinder were immersed. The path to nuclear energy was open, but they did not fully realize what was discovered; four more years were needed to hear it from other scientists (F. Cardone Mignani R. 2000). In November 1938, the liberation of nuclear energy through uranium fission was rediscovered in Berlin by Otto Hahn and Fritz Strassmann, who had freed themselves from the prejudices of Meitner. The phenomenon was baptized by Bohr "nuclear fission" (Jungk, R. (1955).

Trial and error

Since then, the research of nuclear energy use proceeded expediently, already in 1939 were filed the first two patents for the construction of a nuclear reactor. But the outbreak of the Second World War prevented its realization. However, there was no lack of scientific problems. For example, how to use radioactive uranium to produce nuclear energy on a large scale and in large quantities. The chain reaction, in uranium, could only take place under the condition that there was a minimum quantity (uranium critical mass) that had to be calculated, and this was a serious problem. Both Fermi and Heisenberg miscalculated, therefore the French patents of 1939 reported the incorrect result.

The Germans used pressure to get around the problem of critical mass. Starting from a pressure wave they intended to generate a shock wave within any amount of uranium. The main actors were Kurt Diebner, Walter Gerlach and Walter Trinks, who worked from 1943 on nuclear reactions produced or catalyzed by pressure. They realized that the only pressure applied to uranium was not enough to trigger the chain reaction and switched to shock waves (Walker M. 1993). The difference is that the pressure waves have a harmonic (sinusoidal) pattern, while the shock wave is impulsive and violent. They used dynamite in the shape of a hollow sphere.

With the end of World War II, the results of studies on nuclear reactions induced by pressure were largely lost. The first nuclear device (Trinity) that included the Kistiakowsky-Neddermeyer pressure method was tested in 1945 in New Mexico as part of the "Manhattan" nuclear project. Diebner and Gerlach prisoners of war brought their secrets about the use of pressure in nuclear reactions to the grave, so everything had to be rediscovered (Bernestein J. 2001; 2005). The Polish Sylwester Kaliski and the German Friedwardt Wintemberg contributed to the "rediscovery", trying to explore the use of pressure in nuclear reactions. The first realized the thermonuclear fusion via conical explosion concentric with a high degree of symmetry, using deuterium compressed gaseous state (Rich, V. 1977; Derentowicz H. et al. 1977.1979). For the contribution of Wintemberg (1984) what is reported in his text “Autocatalytic fusion-fission implosions” is interesting.

1989-1998: ultrasound, cavitation and thermonuclear fusion

In 1989, Harold Metcalf very much surprised the scientific world with the discovery of sonoluminescenza; in fact it was not expected that sound and ultrasound could cause water to emit light or, more generally, electromagnetic waves that are electromagnetic radiation of which light is a particular case (Metcalf, H. 1998). A series of hypotheses was put in place to explain the mechanism that allowed the waves of pressure of sound and ultrasound to induce the emission of light by liquids, but soon it was realized that the phenomenon was not triggered by pressure alone, but the cavitation. Cavitation is a phenomenon discovered by chance, in the early decades of the twentieth century, from the observation of the small cavities that formed, after a period of use, on the metal propellers of ships. It was discovered that the phenomenon was triggered by small gas bubbles dissolved in the water that instead of burst and release the gas, imploded: collapsing on themselves, causing small cavities on the metal; hence the name cavitation. This process concentrates an enormous amount of energy in a very short time and in a microscopic volume. Sound, in particular ultrasounds, cause, with their pressure, the collapse of gas bubbles dissolved in water at atmospheric pressure and room temperature. All this occurs when the oscillations have a high frequency, that is, from a minimum of 5,000-8,000 up to a maximum of 20,000-25,000 oscillations per second.

Propagation and repeated reflection of ultrasound within water build standing-wave-like acoustic fields; when an ultrasound intensity gradient appears in the acoustic fields, it can in principle induce steady streaming flow. When the ultrasound intensity is sufficiently large, cavitation occurs and oscillating cavitation bubbles are either trapped in the acoustic fields or advected in the flow (Yamashita, T., & Ando, K. (2019).

Noteworthy is the fact that, with the cavitation and collapse of bubbles on their own, the ultrasonic pressure wave is transformed, spontaneously, by bubbles in shockwave. However, this only happens when the pressure wave is larger than the diameter of the bubble it is crushing.

By calculating the light emitted, the temperatures that could be reached by the shock waves were established, which surprisingly turned out to be thousands, then hundreds of thousands and finally even millions of degrees. Obviously, these temperatures had an effect on the atoms of gases and water only at a microscopic level, resulting in the emission of light accompanied by the electrical charges of which the atoms are composed (Brennen C.E. 1995).

The idea of "microscopic nuclear hollow charges" was a rediscovery of the experiments of Diebner and Gerlach. The same criterion used for the construction of German bombs was adopted, that is to perform the cavitation of heavy water (Deuterium), to verify the production of thermonuclear reactions due to the high temperatures estimated for cavitation. In simple terms, it was hypothesized to achieve the "inertial" thermonuclear fusion of deuterium starting from ambient temperature and atmospheric pressure. The term inertial means that deuterium had to be inert before cavitation, but subsequently had to react following the collapse of the bubbles containing heavy water vapor, bubbles that were considered microscopic inertial reactors for thermonuclear fusion of deuterium. An idea that seemed fascinating, but focused on a simplistic view of physical phenomena, for which many scientists attempted the strategy of cavitation with ultrasound in an empirical and heuristic way. They were random attempts that gave alternate results. The inevitable failures led to reflection that led to nuclear reactions induced or catalyzed by pressure (“piezo-nuclear reactions”).

To resume the experiments, after a period of stasis, were the main US institutions: the Department of Defense and the Department of Energy, which for 15 years starting from 1991 have carried out an intense research activity, which has led to the development of two American models of piezonuclear reactions.

The first US model 1992-1998

The first model was developed between 1992 and 1998, it was the first serious attempt to produce nuclear reactions through cavitation, thanks to George Russ who made use of the experience of Yoshiaki Arata. The latter has been one of the most important scholars of inertial thermonuclear fusion within physical systems consisting of metals and light elements, including deuterium (Arata Y. et al., 2004). For clarity it is better to limit ourselves to piezo-nuclear reactions, or more simply to ultrasonic nuclear reactions. Russ’s reactor included a metal plate, a metal whose crystalline lattice was able to absorb hydrogen, or deuterium, and a vessel containing heavy water in which ultrasound was carried. The latter were produced by an electric generator which sent variable electric current oscillating to a column of piezoelectric plates which, in turn, they transformed the electric oscillation of the current into mechanical oscillation of the individual plates and from these the mechanical oscillation was transferred to the water. The aim was to ensure that bubbles, containing heavy water vapors, were compressed by ultrasonic oscillations within the range that triggered the cavitation. Unfortunately, Russ failed to produce an ongoing process, which was enough to determine the failure and abandonment of the project (New Energy Times Issue #32, July 3, 2009:http://newenergytimes.com/v2/news/2009/NET32833xj$.shtml).

The second US model 1999-2002

The Defense Advanced Research Projects Agency (DARPA) conducted the experiment in the two most important national laboratories for nuclear research in the US: Oak Ridge and Los Alamos. In 1999, in Oak Ridge, Rusi Taleyarkhan began the experiments that led to the construction of the second model of ultrasonic nuclear reactor. The Indian researcher was unsuccessful because he made the entire container of liquid vibrate with ultrasound, so the system, highly unstable, was facing continuous breakdowns. But this was a predictable result. As Fabio Cardone points out, the ineffectiveness of the ultrasonic tanks is due to the fact that the ultrasonic pressure transmitted to the external wall of the tank, although considered effective, is unfortunately very different from the ultrasonic pressure transmitted by the tank to the liquid contained in it. The fundamental concept, if we want to induce the metamorphosis of matter into a liquid, is that a generator of acoustic pressure must necessarily be immersed in the liquid to be transformed. We say this in order to clear the field of the misunderstanding, for example, of the concept of centrifugation by means of a container placed in rotation, which would be completely ineffective.

The idea was similar to that of Russ, but in the second model it was intended to generate the collapse of the bubbles directly in the center of the container, and not against the metal plate at the bottom of the container as predicted by the first model. It was intended to make a real reactor in continuous operation. The problem was the choice of the oscillation method of the entire reactor vessel, which was unable to tolerate for long times the 20,000 oscillations per second, which are necessary to generate the phenomenon of cavitation. Possible solutions put in place were disastrous from a scientific point of view. A method was adopted to increase the deuterium content in the bubbles, with the ultimate aim of obtaining bubbles consisting of deuterium only and not of deuterated acetone vapors. The method involved sending neutron pulses from the outside into the reactor container, in this way the neutrons gave their energy of movement in a privileged way to deuterium: the latter is the lightest element among the atoms of the acetone molecule. The system was ingenious but very complex to implement, as neutron pulses had to be synchronized with cavitation and ultrasound. There were also many questions of method: how can a physical system in which neutrons are inserted generate new neutrons autonomously? Can we be sure that it is not the neutrons that are released that generate the neutrons that are produced, or that the neutrons that are introduced are retained by the material of the container and subsequently released by the effect of ultrasound?

The situation created discomfort and the experiments were moved to Los Alamos, but doubts and machine breaks remained. There were many scientific controversies, very few serious scientific discussions. The second US model of piezo-nuclear reaction was the most acclaimed and recognized, an example is the elimination of the metal plate of the first model and the introduction of cavitation in the center and not in the bottom of the container. Having proved that the union of the oscillating system with the reaction chamber, which also vibrated, had proved to be an impractical method, if not wrong from a technical and scientific point of view.

All these experiments have been useful to ask the following question: if the pressure, in the form of pressure wave, shock wave, or by cavitation collapse, can or can not generate or catalyze nuclear reactions. If so, are we facing known or new reactions? (Cardone F. 2016).

The Italian experiments

The studies regarding the piezo-nuclear reactions, in Italy, have respected the tradition of classical culture: a way strictly deductive, unlike the Anglo-Saxon and German heuristic empirical. The experimental results were preceded by theoretical studies involving mainly scientific institutions and some Italian universities. It was assumed that the space around the atomic nuclei was not flat like a sheet of paper lying on a plane, but that for nuclear forces it was possible, within certain limits, to deform space at a microscopic level. The idea of microscopically deformed space would account for nuclear reactions induced, or catalyzed, by pressure and not only known ones, but would also open the way to new possible reactions. A microscopic deformation not easy nor common, but realizable only under specific conditions that were bound to the energy of the two nuclear forces: radioactivity and nuclear force. The first responsible for the instability of the atomic nuclei; the second responsible for the very existence of atomic nuclei. Each of the two forces, in its own way, deforms the space and that is why they must be followed separately. Some Italian researchers focused on the study of nuclear force, within a few years they realized that its deformation of space was related to a very precise and high energy threshold (Albertini G. et al., 2015a; 2015b).

When the binding energy is no longer sufficient, radioactivity intervenes to manage instability, thus allowing the nucleus to emit radiation in succession, until it gradually becomes a stable nucleus. In addition, the phenomenon of the mass defect must be kept in mind, which does not always correspond perfectly to the binding energy.

Previously the experiments were designed as if cavitation transformed the collapse of bubbles in many microscopic nuclear caves, today we know that it is not so. Cavitation is only a means of concentrating sufficient energy to overcome the threshold of deformation of space around atomic nuclei. In this case it is not important the amount of energy that is concentrated, but the short time with which it is concentrated and the duration of the interval between concentrations (Cardone F. and Mignani R. 2004).

Italian researchers had to keep in mind some specific conditions. One of which provided that the element should have characteristics such as to be able to apply ultrasounds at the maximum power that the technique allowed, for the shortest possible duration and before exceeding the deformation threshold of the space around the core of the chosen element, something that would have triggered the piezonuclear reactions with consequent release of nuclear energy. It should also be kept in mind that the deformation threshold depended on the type of element chosen and, above all, on the binding energy of each nucleus. The energy must be released in the form of moving neutrons, the emission of which could, however, be discontinuous (variable pulses in time) in intensity and direction, which would create problems to establish the most convenient use for industrial applications. Another necessary condition is the absence of gamma radiation.

An experimental machine, considered to be the best, was built at the University of Perugia, but it was not portable due to the size of the cooling system; besides, it was not very powerful. It was necessary to have a machine with a good conceptual design of its most important constituents. A machine that had to be an electric voltage generator capable of producing, in a suitable column of piezoelectric materials, 20,000 oscillations per second. Oscillations to be transferred to a steel amplifier which, in turn, would transfer them to a truncated cone-shaped sonotrode whose tip delivered ultrasounds. The tip of the sonotrode must be positioned in the center of the reaction chamber where it releases the ultrasounds, thus obtaining the maximum effect. This was the new technical concept: the sonotrode (and its tip) had to be separated and distinct from the reaction chamber containing the reactive liquid, in such a way as to make the liquid vibrate but not the chamber. The last aspect, but the most important to keep in mind, was the choice of the element to use. Iron was chosen, because it has the highest value of binding energy per component, moreover it is inert: it is not radioactive (Cardone F. 2016).

The Italian project

In Italy the design of the ultrasonic machine (cavitator) was developed by Professor Cardone in 2005. The ultrasonic generator with piezoelectric column was supplied by the German industry Sonotronic (https://sonotronic.de/products/ultrasonic-components/sonotrodes).

The strengths of this apparatus are the separation of the sonotrode, compared to the reaction chamber, and the forced air cooling system of new design. The cooling system is important because there is a need to combine sonotrode and cavitation chamber based on precise proportions, which could be modified by heating, the latter induced by the vibrations that generate ultrasounds. In short, cooling prevents thermal expansion from modifying the geometry of the sonotrode compared to the reaction chamber. The machine reached the power of 100 watts of ultrasound, transferred to the center of the chamber. A power that corresponds to an amplitude of oscillation of the tip of 30 microns, at a frequency of 20,000 oscillations per second. These data are essential to establish the final volume to be treated: 300 milliliters, and the ultrasound application time: 90 minutes. In the experiments, iron, aluminum, lithium and thorium were used, in order. Iron, aluminum and lithium were used to verify the time of inertia before the emission of neutrons, as well as to verify the emission of neutrons from iron. Thorium was needed to verify the behavior of a radioactive element compared to inert elements. In these experiments the presence of signals produced by neutrons was confirmed, what is important was that no alpha and beta radiation were recorded outside the reaction chamber. Furthermore, in all conditions there was no emission of gamma radiation. (Mignani R. et al. 2009).

The choice of thorium, for the experimentation carried out in 2005, was inspired by the Russian experiments, which involved the use of shock waves from electrical explosions in aqueous solutions and radioactive substances. Furthermore, thorium-228, having a nucleus composed of 90 protons and 138 neutrons, is a hexa-alpha-emitter, which is equivalent to saying that it transforms radioactively by emitting six alpha particles. After being subjected to cavitation with a power of 100 watts and a frequency of 20,000 oscillations per second, for a total of 90 minutes, the samples (300 ml) were analyzed with a high resolution mass spectrometer (quadrupole with magnetic sector). The thorium content was halved, as was the specific radioactivity; all without neutron emission and in 90 minutes, instead of the necessary two years. For the transformation of thorium into lead, due to the pressure of a shock wave, the experiments of Urutskoev (2004) were important. All this leads to the conclusion that thorium has been subject to piezo-nuclear reactions, capable of modifying its nature by making it exceed the energy threshold of the radioactive force, beyond which even the geometry of this force is no longer flat (Mignani R. et al. 2009).

If all this happened with liquids, the positive results were not delayed when treating solid materials (Cardone, F., Carpinteri, A., & Lacidogna, G. 2009). The first measurements, although partial and incomplete, of the energy spectrum of neutrons produced with steel bars followed (Cardone, F., Mignani, R., Monti, M., Petrucci, A., & Sala, V. 2012). However, it was an important result, because for the first time the characteristics of the neutrons produced by new forms of nuclear reactions were detected and measured. All confirmed by the experiments conducted from 2010 to 2013 at the Rome-Cesano laboratories of ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development) (Cardone F. et al., 2015c). Among privates such as Startech of Milan and Meccano of Fabriano excelled. Between 2009 and 2015 they have been studied mutations occurred in both liquid and solid substances containing iron, solutions of iron salts of different chemical compositions and above all metal alloys of iron of different types, such as one of the most common called AISI -304.

The patents resulting from research Cardone and co-workers have been filed by the National Research Council (CNR). The first patent of the CNR concerning the removal of radioactive substances, nuclear reactions using ultrasound, has been published on the CNR website until 2015, when it was finally sold together with the second and third patents (EPO database).

The piezo-nuclear reactions examined by the CNR researchers can be divided into two broad categories: exothermic ultrasonic reactions and endothermic ultrasonic reactions. These ultrasonic reactions, understood as piezo-nuclear reactions, are valid both in liquids and in solids, following the experiments carried out at the Turin Polytechnic and the tests conducted in Milan with the small-scale prototype of a piezo-nuclear reactor.

It could be possible to build up to about 10 products, at least in the production of neutrons and consequent thermal effect (Sala V. et al., 2012). Today, it is possible, through ultrasound, to quickly transform toxic matter and elements into substances rare in nature. It should be borne in mind that this transformation does not occur with all types of ultrasound, but must be carefully and delicately piloted. An example is mercury, which can be transformed into other elements (Table 1). We report in the following table 1 all the products of the metamorphosis of mercury highlighting the Rare Earths. This table refers to the scientific articles published in the bibliography.

Z (atomic number) / element	**Rare earth**	**Element / Isotope**	**Other Element / Isotope detected**
3 Lithium		^{7}Li (1°)	

4 Beryllium			^{9}Be (mono)
22 Titanium		^{47}Ti (3°)	
23 Vanadium		^{51}V (1°)	
27 Cobalt		^{29}Co (mono)	
28 Nickel		^{58}Ni (1°)	
31 Gallium		^{69}Ga (1°) ^{71}Ga (2°)	
32 Germanium			Ge
34 Selenium		^{78}Se (2°) ^{82}Se (4°)	
35 Bromine		^{79}Br (1°)	
37 Rubidium			Rb
39 Yttrium	Rare earth		^{89}Y (Mono)
42 Molybdenum			^{95}Mo (3°) ^{98}Mo (1°)
48 Cadmium			^{111}Cd (3°)
49 Indium			^{113}In (2°)
50 Tin		^{118}Sn (2°) ^{124}Sn (6°)	
51 Antimony			^{121}Sb (1°) ^{123}Sb (2°)
58 Cerium	Rare earth	^{138}Ce (3rd) ^{140}Ce (1st)	
63 Europium	Rare earth		^{151}Eu (2°)
64 Gadolinium	Rare earth		^{152}Gd (7°) ^{158}Gd (1°)
70 Ytterbium	Rare earth		^{174}Yb (4°)
71 Lutetium	Rare earth		^{176} Lu (2°)
72 Hafnium		^{177}Hf (3°)	
75 Rhenium			^{185}Re (3°)
78 Platinum		^{190}Pt (6°) ^{195}Pt (1°) ^{196}Pt (3°)	
79 Gold	^{197}Au (Mono)		
90 Thorium	^{232}Th (Mono)		
92 Uranium	^{238}U (1st)		

Table 1. Reaction products of mercury metamorphosis in order by atomic number Z. In parentheses, the position of the isotope according to the natural abundance on Earth, 1st, 2nd, 3rd, ... isotope. Mono = naturally mono-isotopic element on Earth. In red, the elements called rare earths are indicated. This table summarizes the results obtained from the experiments conducted for the metamorphosis of mercury reported in the bibliography.

It should be emphasized that what is reported in table 1 is the result of the metamorphosis of mercury; it is obvious that changing the element can change the result. It is also specified that the rare earths known today are 14-17 depending on the authors who report them. In the case of mercury, about half of the known ones have been produced.

Mercury is an important substance in many industrial manufacturing and metallurgical processes,[1] in particular due to its characteristic of having electronic affinity[2] with the majority of both light and heavy metals such as gold.

Unfortunately, its toxicity has been widely recognized, up to its poisonousness,[3] so it has been excluded from many industrial and manufacturing processes, the most striking case being that of European Union (EU) legislation. In fact, in the EU countries the use of mercury in any process that leads to a marketable product has been definitively banned, so mercury has become a "special" waste.

Through the metamorphosis of matter it was possible to change a mole of mercury (about 200 grams) into other elements by applying the acoustic pressure through ultrasonic sonication in order of 100-180 seconds.[4]

The products generated by this transformation have been varied and multiple and cover about one third of the known elements in the periodic table of elements. The most important thing is that among these products there are about half of the known Rare Earths, this is a fact of great practical importance and potentially enormous economic, industrial and even geopolitical consequence. We do not delve into these last aspects limiting ourselves to ascertaining the equally fundamental fact that a pollutant, in addition banned, can become a source of raw materials thanks to the “isotopic change” induced by the metamorphosis of mercury by means of acoustics.

Current technology allows us to build new and versatile machines (Cardone F. et al., 2015d).

In 2015, it was possible to definitively identify the physical (non-chemical) process that leads matter to change the nature of the component elements under the effect of acoustic pressure, this phenomenon was definitively baptized by the discoverers the "Metamorphosis of Matter" in honor of the great Sulmona poet Publio Ovidio: author of the immortal poem “the Metamorphoses”.

Subsequently, this phenomenon was experimented and studied in mercury and led to its definitive recognition, in particular the ability to transform matter without using radiation and without generating radioactivity, but even to produce useful substances such as rare earths from a harmful substance such as mercury. From 2015 to 2020 the study of the neutralization of radioactive substances by metamorphosis of the material applied to acidic radioactive solutions containing the artificial radioactive isotope Nickel-63 was resumed. This latest study on radioactive acid solutions has been explicitly designed for waste from the military nuclear industry, in particular waste from cold metallurgical processes for the preparation of Plutonium; the latter is the main nuclear explosive currently in use.

As already reported, the first evidence of the "Metamorphosis of Matter" was published in 2009, the first complete test in 2015, the year in which a generalized picture of the situation was made.

With the new industrial processes of acoustic transformation of matter, that is the sonic metamorphosis of matter, it is possible the neutralization of radioactive substances that makes a dangerous pollutant harmless and it is possible that mercury, from a pollutant, can become a source of useful raw materials, indeed strategic, such as rare earths. This concept of use can also be applied to chemically harmful pollutants, both inorganic from the manufacturing industry and organic from the agro-food industries.

In this article we do not aim to describe the potential, although important, of ultrasound in the therapeutic field. Are known advancements in ultrasound-enhanced drug delivery strategies, that have demonstrated remarkable success in providing targeted drug delivery for a broad range of diseases. In order to achieve enhanced drug delivery, these strategies harness the mechanical effects from bubble oscillations (i.e., cavitation) of a variety of exogenous cavitation agents (Thomas, R.G. et al., 2019).

Perspectives of de-pollution with metamorphosis of Matter

We do not consider solid substances for the moment but we report the prospects for liquid substances where the process of metamorphosis of matter has given the most promising results. There are various technical ways to induce sound pressure in a liquid placed at room temperature, atmospheric pressure and normal earth gravity at sea level. The three main methods can be summarized here: mechanical centrifugation of the liquid by means of rotors immersed in it; the gasification of the liquid by forced introduction under pressure of air, both with normal cylindrical pipes and with Venturi pipes that use conical sections; Finally, the classic method of ultrasound, introduced into the liquid by means of sonotrodes in immersion, as the method of metal tanks ultrasonic has proved ineffective to produce the metamorphosis of matter.

From the case of mercury, we take a cue to talk about inorganic waste containing heavy oils from the mechanical industry. For this type of polluting liquids the best method to transform them has until now been the result of centrifugation using a mechanical rotor immersed in the liquid itself. The process of transferring the acoustic pressure generated by the rapidly rotating rotor has shown the effect of splitting the molecules and then transforming the atoms with the phenomenon of the metamorphosis of matter. In this way, a generally harmless liquid was obtained.

As regards the organic waste from the zootechnical food industry, both the centrifugal method and the ultrasonic method have been tested, obtaining in any case both the reduction of nitrites and nitrates with the consequent transformation through metamorphosis of the material until reaching a surprisingly liquid comparable to non-potable water, but free of pollutants and as such dispersible in the ground and can also be used for irrigation purposes.

Regarding to organic-inorganic wastewater from leather manufacturing, all three methods were used and tested with results similar to those obtained with organic waste.

With regard to agriculture even irrigated wastewater containing nitrogen compounds from fertilizers may also be subject to processes of metamorphosis of matter with possible analogues of decontamination results.

Outline of the project for the depolluting device

There is a company in Italy that is preparing this type of sonicators that perform the metamorphosis of matter with the acoustic pressure method obtained by ultrasound and applied to both liquid and solid materials using sonotrodes of suitable shape and metal alloy.

This company has expertise in three things: radioactivity, energy, and hadron therapy, but not the metamorphosis of matter.

We have neglected the problems related to the production of energy and the neutralization of radioactive substances and, likewise, with the generation of emissions by anti-tumor neutron hadron therapy. We focused on the metamorphosis of matter as the main phenomenon for the de-pollution of liquids. In the current state of technical knowledge, the ideal de-polluting device for a liquid can be a three-stage centrifugal-gasifier-sonicator system which, by dissociating and "metamorphosing" the chemical compounds and the elements that compose them, obtains the desired effect of rendering the poisonous liquids harmless or, when possible, produce from them useful elements for industrial purposes.

For the reader interested in deepening the question of the metamorphosis of matter as a nuclear metamorphosis that generates the "isotope change" that is the transformation of the isotope of an element to that of another element, we refer to the brief but essential bibliography of this chapter and in particular to the aforementioned work "the future energy".

NOTE:

1. In metallurgical processes it is fundamental because it amalgamates with metals separating them from each other. Even in the mining industry it is useful if not essential for cold extraction of metals from raw ore.
2. By electronic affinity we mean the change in energy, changed in sign, which occurs when a neutral atom in the gaseous state acquires an electron becoming a negative ion.
3. It depends on the concentration in the living organism.
4. The aforementioned mass of mercury was suitably treated by ultrasound to generate in it the same conditions of violation of the local Lorentz invariance, through a cylindrical bar sonicator in AISI 304 steel, which causes the emission of neutrons during sonication. After 3 minutes, part of the mercury transforms into a solid material that contains isotopes having a different mass (greater and lesser) than the isotopes already present in the initial material (mercury). These transformations of the atomic weight without gamma production occur during the so-called Deformed Space-Time reactions, the piezonuclear reactions are a particular case.
5. The sonotrode is the metal part, made of suitable alloys, which transforms and transmits the electromechanical vibration into vibration and acoustic pressure in the material in which it is immersed or in contact. Its name is due to the analogy with the electrode, as the electrode transmits electricity in the form of electric current, so the sonotrode transmits acoustic pressure in the form of mechanical vibration.

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