EXPLOITATION OF SHALE GAS BY HYDRAULIC FRACTURING - A METHOD WITH POSSIBLE MIDDLE AND LONG TERM CATASTROPHIC CONSEQUENSES

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ABSTRACT

In the hydraulic fracturing method the main quantity of fracking fluid (50-90%, waters with noxious additives) remains in the underground of the exploited areas, at various depths. The exploitation is more advantageous as the quantity of fracking fluid refluxed at surface is smaller. But in the same time, the greater the quantity of this fluid remained underground, the greater the possibility of a future contamination. These toxic fluids are quartered in the mother rocks affected by fracturing, represented by argillaceous rocks rich in organic matter. Nevertheless the fracking fluids can reach the surface during medium or long periods of time by various ways and because of various causes. For this reason it is important to stress on the fact that the hydraulic fracturing surely disturbs the dynamic equilibrium of the rocks covering the mother rocks attacked by fracturing, especially in the case of unconsolidated rocks (sands) and carbonaceous rocks (limestone). This disturbance is caused mainly by the great number of microseisms resulted from the fracturing process. Subsequently, after the end of the exploitation, surface instability phenomena become probable because of large quantities of gas or oil extracted from underground. These phenomena are well-known even after classical oil or gas exploitations. One way for the contaminated waters to reach the surface is the natural fault systems existent in the deposits above the exploited productive horizons. These faults are sometimes very difficult to detect, but they are always present, even in the platform areas in which the productive formations generally are to be found. Along these faults the toxic solutions and the methane gradually enter the permeable rocks i.e. deep aquifers and, closing to the surface, the phreatic waters and finally the hydrographic network. The natural seismic activity produced after the ending of exploitation can facilitate the access of the contaminated waters or methane towards the surface, especially in the situation of powerful seisms. After various periods of time, at surface, in the areas previously exploited by this method, it can appear contaminated waters springs which can more or less directly put in danger human, animal and vegetal life on large or even huge areas if the hydrographic network is contaminated. Also the closed wells, previously used for this type of exploitation, become contamination sources because of the continuous degradation in time of the cement isolation. All in all this method is dangerous for the natural resources of drinking and industrial waters (as strategic resources), connected with deep aquifers, phreatic waters or stream systems. In many zones there are valuable natural resources of mineral or geothermal waters that can be compromised. It is also important to mention that in the areas exploited with this method, the future drillings (whatever their purpose is) can be dangerous no matter if they reach the productive horizon or remain in the formations above. If they will open aquifers above the productive horizon they may find already contaminated waters and may facilitate their access to surface. From this perspective we consider the aggressive exploitation of the underground deposits by hydraulic fracturing as a planting of an ecological bomb with delayed effect, which will cause in the future at least catastrophic eco-phenomena at regional scale.

Key words: fraking fluids, pollution, mother rocks, flow-back , fault sistems, dynamic equilibrium, microseisms.

INTRODUCTION

Exploitation of shale gas by large scale hydraulic fracturing is more and more associated with major situations of environment pollution. Water pollution with methane and additives from the fracking fluid, air pollution and soil pollution with dangerous organic substances, heavy metals and radioactive matter. This is why it becomes imperative a very thorough knowledge of these evil realities and the outlining as precisely as possible of a lot of potential negative consequences, hardly foreseen for the time being. From historical point of view, this type of exploitation, already very controversial, is the last from a series of human interventions on geological deposits containing free or shale oil and gas reserves, susceptible to industrial exploitation. In a first phase exploitation has been performed on oil and gas fields contained in permeable or fractured rocks where hydrocarbons accumulated after their anterior migration. This phase will end after depletion of this type of reservoirs. This type of exploitation was intensified by raising the pressure in the reservoirs by formation water injection (re-injection) and even by hydraulic fracturing of low permeability reservoirs (e. g. sandstone). The next step is exploitation of oil and gas reserves remained captive in deposits which can be considered their mother rocks: pelitic deposits (shale) with high organic matter content (derived from fossil organisms). This content can reach in rare cases ~20%. A primary general analysis of the large scale hydraulic fracturing exploitation method of shale with high organic content leads us focus to the large quantities of residual (contaminated) water remained in the underground of the exploitation areas which represent a major pollution source in the near and/or far future because of the possibility of their migration to the surface. If we neglect in this analysis all economic aspects, we are left to look this type of exploitation as a sustained large scale underground pollution activity, with a lot of harmful substances which, in time, will cause persistent pollution of aquifers, phreatic water, hydrographic networks and soils on large areas. From this perspective the unconventional hydrocarbon reserves exploitation by large scale hydraulic fracturing appears as an aggressive action affecting the geological environment aimed by this process, in various ways. In this context, our paper, with a high degree of originality, is a first attempt to expose the possible major hazards associated in the future with this exploitation method.

CONTAMINATIONS WITH DRILLING FLUIDS IN THE EXPLORATION PHASE

The main objective in the exploration phase (reaching and sampling the mother rocks) implies also crossing the formations covering them. In the drilling process are often crossed permeable, unconsolidated rocks (sand, poorly consolidated sandstone, gravels, etc.) in which fluid losses are produced. If in these rocks there is potable water, it suffers inevitable contamination with additives contained in the drilling fluid. A serious situation appears in limestone with karstic hollows where fluid losses are much greater. If this karstic limestone is also a potable water reservoir, the contamination has much more severe effects. The pollution effects are especially severe in the situation of natural circulation of this water through sandy or carbonaceous aquifers.

NEGATVE ENVIRONMENTAL EFFECTS ON SHORT TERM INDUCED BY HYDRAULIC FRACTURING EXPLOITATION

Among the most important effects can be mentioned the following: the conversion of large volumes of waters in contaminated fluids, the destructive action on geological environment, the making up of anthropic aquifers with toxic composition, the methane pollution of aquifers, and also other different effects.

CONVERSION OF LARGE VOLUMES OF POTABLE AND INDUSTRIAL WATER IN CONTAMINATED WATER (FRAKING FLUIDS)

The hydraulic fracturing process is preceded by the preparation of the fracking fluid in huge quantities. Its main component is water from rivers, phreatic levels or from not so deep aquifers. A good deal of water is requested. This water is mixed with sand (~ 5%) and additives (in great number) which confer toxicity to this fluid. Sometimes fresh water is mixed with flow-back fluids from previous fracturing which make it more toxic) . Although the amount of additives in the fracking fluid is low when compared with the huge total volume, their high toxicity is enough to make it a contaminated water. A fracking fluid made of fresh water and flow-back fluid contains ~ 80% fresh water, ~ 14% flow-back fluid, 5% sand and ~ 0.75% additives. The additives set contains acidic solutions (with HCl), friction reducers, bactericides, scale inhibitors, corrosion inhibitors, various tensioactive agents, etc. The flow-back fluids contain also gases, new chemical substances resulted from reactions between additives and components from the formation rocks, radio-nuclides, much more toxic.

THE DESTRUCTIVE ACTION ON GEOLOGICAL ENVIROMENT (HYDRAULUIC FRACTURING OF THE GAS/OIL MOTHER ROCKS)

Forcing in the mother rocks (shale) of large quantities of fluids under high pressure provokes their artificial fracturing. Their dynamic equilibrium is suddenly compromised and the original physical and chemical properties are modified. The large quantities of gas evolved from the rock and extracted by exploitation wells furthermore disturb this equilibrium.

FRACTURED MOTHER ROCKS SATURATION WITH CONTAMINATED WATER (MAKING UP OF ATYPICAL ANTHROPIC AQUIFERS WITH TOXIC COMPOSITION)

Most of the fracking fluid remains in the underground after the exploitation is ended. Only a minor part comes back at surface as flow-back fluids. In general ~ 50-80% of the total quantity of fracking fluid remains in the underground (often up to 90%). These fluids remain captive in the mother rocks which suffered fracturing because of this technology. This water can also be drawn along faults pre-existent in the shale before human intervention. From the technological point of view it is important that the part of fracking fluid remained underground to be as great as possible. But in the same time the greater the quantity of fluid remained captive, the greater the risk for these contaminated fluids to move upwards in the superficial levels of the sedimentary sheet. The fracking fluids remained in the mother rocks, in the underground of the exploitation areas, are in fact anthropic aquifers in a fissured environment, containing contaminated water with a greater chemical reactivity, more corrosive and toxic than the ordinary water and with a greater pressure. Their composition is different from area to area depending on fracking fluid recipe and on the composition of the formation which suffered hydraulic fracturing.

DETERIORATION OF THE DYNAMIC EQUILIBRIUM OF THE FORMATIONS BETWEEN THE MOTHER ROCKS AND THE SURFACE

The microseisms associated with hydraulic fracturing operations or with the re-injection of the flow-back residual water may disturb the dynamic equilibrium of the formations above the exploited horizons, up to the surface. The most affected will be the formations with a precarious dynamic equilibrium and those with poor plastic properties. It is the case of gravels, sand, poor consolidated sandstone and also the carbonaceous rocks with advanced karstic phenomena. Obviously in areas with greater seismic sensibility the magnitude of these microseisms caused by human activity and their effects will be greater. In this context it is possible that in the deposits between the mother rocks and the surface, cracks or even faults could be created in the rocks with poor plasticity (limestone, consolidated sandstone, etc). This can arrive in extreme cases to a growth of fissures and fracture extent in this type of rocks, with a drastic modification of their mechanical properties.

METHANE POLLUTION OF AQUIFERS

It is already well known that in some areas of US (e. g. North Dakota), around the shale gas exploitation sites, aquifers contain considerable amounts of methane, much above the admissible limit. This situation provoked debates which imposed the syntagm “methane pollution” to describe this particular type of contamination. It is absolutely clear that the exploitation of the Marcellus and Utica Formations in US brought methane contamination of aquifers (Osborn et al., 2011)[6]. Near the working wells methane concentration in drinking water was in many cases as much as ~17% greater than in areas not connected with shale gas exploitation. It must be stressed here that although methane is not toxic, it brings explosion hazards when its concentration is high. On the other side because the great quantities of methane resulted in production cannot be stored completely, large quantities of gas are burned on site with the result of air pollution. Other toxic substances which appear in this technology are: hydrogen sulphide, benzene, ethyl-benzene, formaldehyde, acrolein, propylene, toluene, xylene, hexane, polycyclic aromatics, etc. (Heinberg, 2013) [2].

OTHER CERTAIN FORMES OF SHORT-TERM POLLUTION

In addition to those mentioned above it can be remembered also other recognized forms of pollution, already recorded and analyzed in different aspects [4], [5], [7]. Among them a special place is occupied by the accidents related to the handling and the treatment of the waste water (the flow-back). In plus there are intentional spills of these fluids in rivers or the discharges of improperly treated waters. Sometimes the air and soils pollution is provoked by the spraying into atmosphere of these harmful fluids, a very serious situation is when these waste water contain heavy metals or radioactive elements. It may be mentioned here too the infrastructure damage by heavy transports, the noise pollution associated with all stages of the exploitation, the occupation of important surfaces of agricultural land, the destructions caused by the micro-seismic activity associated with the hydraulic fracturing. Here it can be mentioned also the destructions caused by the microseisms connected with the special drilling injections of the waste water.

APPARITION OF BARRED OR EXTREMELY RISKY ZONES FOR EXPLORATIONS BY DRILLING FOR ANY OTHER PURPOSE

Another major disadvantage of the shale gas by hydraulic fracturing is the apparition of large areas on which executions of drillings for other purpose could be risky or non-indicated or banned. Obviously the crossing of formations contaminated by fracking fluids by such a drilling may lead to a contamination of the drilling fluid. Even if the final depth of a future drilling is above the gas mother rock, it can arrive in a contaminated formation and the sampling of this formation may be compromised. The worst situation is that of a drilling looking for opening and exploitation of an aquifer which is found already contaminated.

POSSIBLE POLLUTION EFFECTS IN THE NEAR AND DISTANT FUTURE

Obviously the anthropic aquifers from the fissured rocks containing contaminated water, formed in the underground after hydraulic fracturing exploitations represent a potential pollution source in a more or less distant future. The pollution effects result either from the migration to the surface of the contaminated water along the fault planes of the rocks covering the productive horizon, or by moving along the wells casing whose cement isolation becomes deteriorated after various periods of time. These effects consist in: deep aquifers contamination, pollution of the phreatic water and pollution of the hydrographic networks.

MIGRATION OF THE CONTAMINATED WATER ALONG THE FAULT SYSTEMS OF THE EX- EXPLOITED AREAS

The most favorable situations for the movement of these toxic fluids are represented by the existence of fault systems in the deposits above those with contaminated water. The fracking fluids move slowly upwards along the fault planes realizing successively the saturation of the permeable or fissured rocks containing these faults. Only thick levels of impermeable and plastic rocks (like clays) can slow down or stop this process, but such protective shields may not be existent in every situation. This migration can be facilitated by fault systems existent in hard rocks or by the existence of holes of karstic origin. It must be mentioned here that even in platform areas, shale gas drillings in the unfolded sedimentary sheets can meet breaking deformations as fissures or faults with small throws. Also the most recent deposits, even the Quaternary ones may contain dislocations. The idea of a platform sedimentary sheet without any fault system is unrealistic. Another way for the contaminated fluids to move to the surface is through the degraded cement isolation of casing at the closed exploitation wells. The natural degradation of cement can be aggravated by cracks in this insulation which appear after subsequent earthquakes. In many cases there are initial flaws after cementing the casing. Some examples of errors in the drilling and exploitation wells on Marcellus Formation in Pennsylvania can be found in the literature (Ingraffea A. R., 2012, in Heinberg, 2013) [2]. All in all it can arrive for these abandoned wells to become anthropic pollution sources with contaminated water.

DEEP AQUIFERS POLLUTION

Contamination of the deposits above the productive horizon may start with various depth aquifers which will receive inputs of fracking fluid which is starting to move upwards. Along the fault planes or around the casing of closing wells the fracking fluid may reach one by one aquifers existent in the permeable rocks (sand, sandstone) or in fissured or karstic rocks (limestone). It is clear that the first to be contaminated will be the deepest aquifers, just above the exploited shale levels. Aquifers near the surface can be for some time safer. The pollution degree of the aquifers between the mother rocks and surface depend very much on the physical properties of the formations and on lithological and structural characteristics of every area.

PHREATIC WATER POLLUTION

After a long period and in a lesser extent the residual fluids can contaminate the phreatic water existent near surface in permeable and porous formations like sand and gravels. Also this can happen rapidly from the surface in the production sites. This pollution is a severe situation because these are water reserves human, animal and vegetal life and for agriculture [1]. In the same time this water is a source for natural springs and hydrographic networks which can spread the contamination on huge areas.

HYDROGRAPHIC NETWORK POLLUTION

In the situation in which deep aquifers or phreatic water can be sources for some flowing waters, these can spread contaminations downstream to the level of a hydrographic network. Although contamination level is thus diminished, it can be spread more and more in the case that this hydrographic network is source for other phreatic water levels or other aquifers in which contaminants can accumulate if their income is continuous. Accumulation is especially possible for the suspended solids, heavy metals and radio-nuclides resulted from a mixture of fracking fluids with components from the rocks which suffered hydraulic fracturing.

THE MAJOR ROLE OF STRONG EARTHQUAKES IN ACCELERATION OF CONTAMINATED WATER MIGRATION

Usually we imagine that contaminated water captive at various depths has minimal chances to reach the surface or they are very slowly moving upwards. The situation is entirely different in the situation of strong seismic shocks. Migration of the contaminated fluids to the surface is anyway favored by seisms with medium magnitudes, but in the situation of very strong seisms the chances for these fluids to reach the surface are much greater. The seisms with exceptionally great magnitudes may induce even the raising of fissures number in the formations between the productive horizon with toxic fluids and the surface. Old latent faults can be reactivated, even new faults can appear. If these strong earthquakes find the contaminated fluids in an advanced migration stage towards the surface, then their effect is stronger. It is not hard to imagine that these very strong earthquakes which are nor rare at all at the geological time scale (one/several hundred years or one/several thousand years) could bring, besides their devastating effects, catastrophic contamination of aquifers, phreatic water and hydrographic networks with deadly effects for mankind. Also we could assist to a sudden arrival at surface of these contaminated fluids along the fault planes, affecting large areas at surface.

THE "HEREDEA" PERSPECTIVE ON THE NATURE OF SHALE GAS EXPLOITATION

After an analysis of all data available on the shale gas exploitation, Heredea N., a Romanian geophysicist, arrived at the conclusion that this technology is in fact an activity of triggering a series of anthropic geochemical reactions in the formation, the main gas resulted (methane) is of non-biotic origin [3]. So, the so-called shale gas is in fact natural combustible gas resulted from human intervention on the shale: we should talk not about "obtaining" or "exploitation", but about "fabrication in situ" by a series of chemical reactions from which result gaseous hydrocarbons. The so-called exploration wells are in fact devices through which uncontrollable and irreproducible experiments are made to test various recipes of chemical solutions. The shale is the raw material and the additives are the chemical reagents. All this technology is a deliberate pollution activity. Substances are introduced in the geological environment and so it is created in situ a "chemical reactor". The chemical reaction field will advance along the minimum resistance directions in the fractured formation and also depending on spatial distribution of the components in the mother rock which participate at the reactions with the additives introduced through the well. The term "hydraulic fracturing" covers in fact a completely different reality: gas factories, very profitable ones, chemical reactors. In great number they make a huge chemical complex, with no technologic security rules and no waste disposal obligations. After this "exploitation" the geologic environment is no more natural, the rocks become a mixture of waste products with a lot of toxic fluids, hidden in the underground. We can start to talk about the geochemical cycles of chemical-made gas, of toxic fluids during the geological time. Consequences can be severe, even catastrophic.

CONCLUSIONS

Shale gas exploitation by hydraulic fracturing technology is an aggressive anthropic action on the geologic environment with severe, even catastrophic consequences in the more or less distant future. Besides the possible contamination effects in the exploration phase and the different types of immediate air, water and soil pollution around the working sites, this method, using an "incorrect technological regime" (according to classical terminology of the conventional oil and gas fields exploitation) brings also the following undesirable and doubtless effects:

- Conversion of huge quantities of fresh water (potable, industrial) in toxic, contaminated fluids (the fracking fluids);
- Irreversible destruction of entire levels of the geologic environment (shale destroyed by fracturing);
- Formation of atypical, anthropic, contaminated aquifers containing fracking fluid additives, substances resulted from their reactions with mother rock components, radio-nuclides, etc.
- Disturbing the dynamic equilibrium of the formations between the productive horizon and the surface, especially in the case of porous rocks (sand, sandstone) or calcareous rocks with karstic phenomena;
- Converting all these exploitation areas in forbidden zones for other future exploration drillings with any other objectives in the formations above the exploited horizons;

In more or less distant future the geochemical migration of the contaminated fluids along the fault planes or around the abandoned exploitation wells will lead to the contamination of aquifers, phreatic water and hydrographic networks and then of the soils on large surfaces. This process is favored by earthquakes produced after the exploitation end and very much accelerated by the very strong seisms which are anyway probable.

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