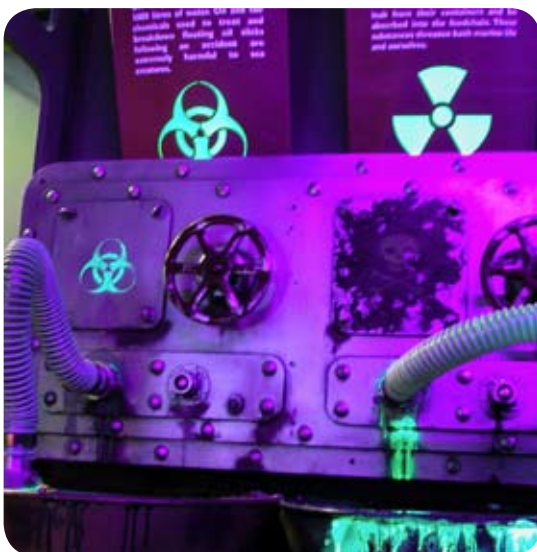


*A COMMERCIAL APPLICATION OF
VIROMINE™ AND VIROFLOW™ TECHNOLOGY*

RADIOACTIVE ELEMENTS TREATMENT

TECHNICAL PAPER



INTRODUCTION

In addition to specialising in the treatment of heavy metals, such as lead, mercury and chromium, and a variety of other inorganic and organic contaminants in water, soil and solids over the past ten years, Virotec has also developed treatments for a variety of radioactive elements. The purpose of this Technical Paper is to summarise the findings from these various applications.

There are a vast number of radioactive elements in the environment, and radiation is a naturally occurring phenomenon which affects our everyday lives. Radioactive elements are often present in the form of radionuclides, which are atoms with unstable nuclei (i.e., nuclei characterized by excess energy available to be imparted either to a newly created radiation particle within the nucleus or to an electron). Under these conditions, radionuclides undergo “radioactive decay”, emitting gamma ray(s) and/or subatomic particles, a process which may occur naturally, such as potassium-40 (^{40}K), but can also be artificially generated by manmade nuclear reactions and/or accidents and other processes, such as strontium-90 (^{90}Sr) and technetium-99 (^{99}Tc) from nuclear medicine and in the recent nuclear disaster at the Fukushima power plant in Japan where large amount of iodine-131 (^{131}I) and caesium-137 (^{137}Cs) were released into the atmosphere, contaminating surrounding land, water and air, and in the earlier 1986 Chernobyl disaster in Ukraine.

The most common radioactive elements generated from artificial sources include uranium (U), thorium (Th), caesium (Cs), strontium (Sr), potassium (K), and iodine (I); one of the most common naturally occurring radioactive elements, particularly in U.S. drinking water, is radium (Ra) and its decayed gaseous daughter radon (Rn), which can further decay to form ^{210}Pb (i.e., gaseous lead). Radionuclides are referred to as “radioactive isotopes” or “radioisotopes”, which can present a significant and ongoing danger to human and environmental health unless contact can be minimised.

HEALTH RISKS ASSOCIATED WITH RADIOACTIVE ELEMENTS



Aerial view of the Chernobyl nuclear reactor after the 1986 explosion.

A nuclear and subsequent radiation accident is defined as “an event that has led to significant consequences to people, the environment or the facility. Examples include lethal effects to individuals, large radioactivity release to the environment, or reactor core meltdown.” The prime example of a “major nuclear accident” is one in which a reactor core is damaged and large amounts of radiation are released, such as was the case at both Chernobyl and Fukushima.

The threat of a nuclear accident has been a topic of debate since the first nuclear reactors were constructed. It has also been a key factor in the public’s concern about nuclear facilities. Although measures to reduce the risk of accidents or to minimize the amount of radioactivity released to the environment as a result of an accident have been adopted, there have been near misses, incidents and serious nuclear accidents which have caused varying degrees of short- and long-term problems for individuals and the

environment; naturally occurring radiation, such as radium in drinking water, has also posed ongoing health risks to those being exposed.

The effects of radiation on humans depend on a number of factors, including the dose of radiation, the dose rate, the intensity of the dose, and the criticality and sensitivity of the exposed parts. As was the case at the Fukushima power plant, radionuclides like caesium and strontium were released into the atmosphere as a result of explosions and/or breakdowns in the nuclear reactors. These radionuclides can enter the human body through inhalation or ingestion, and deposit in target organs. For example, strontium and caesium are both deposited in bones and lungs potentially resulting in damage to the DNA; such absorption of radionuclides can lead to mutations, which cause a range of diseases, including various types of cancer.

Radionuclides also contain charged particles like photons, alpha particles and electrons. The density of ionisation (i.e., the formation of ions as a result of a chemical reaction, high temperature, electrical discharge, particle collisions, or radiation) and excitation of the radionuclide caused by these particles is high and thus results in greater damage to human tissue. For example, electrons are light and their energy loss per unit distance travelled is much smaller than that of alpha particles of the same energy. Thus, the energy of electrons is distributed into a greater volume and the impact they cause on human tissue is much smaller.

Photons, on the other hand, reach deep into tissue and require many centimetres of lead to provide an effective shield; neutrons are uncharged and interact only with other nuclei, but they induce changes in the atoms and molecules they reach. When human tissue cells are hit by emitted charged particles, many abnormalities may result. In this case, water, about 80% of the total contents of a cell, gets ionised to form free radicals which interact with target molecules like membranes, biomolecules and biomacromolecules like DNA and cause damages.

The biological damage rendered after the body has been irradiated is categorised into three types: acute, delayed and genetic effects. Acute effects are expressed as a few days. Nausea, vomiting, diarrhoea, loss of appetite and uneasiness are initially noticed and depending on the radiation dose, the severity of symptoms may increase. The radiation dose yielding 50% lethality (LD50) in the exposed human population is considered to be about 3.0-3.5 Gray (Gy), and people engaged in rescue operations are often allowed to receive doses limited to 0.5-1.0 Gy. Within two weeks after an exposure of 3.0-4.0 Gy the symptoms of the failure of bone marrow may start appearing and may lead to death within a month due to haemopoietic failure. Higher doses (more than 5.0 Gy) may lead to failure of the gastrointestinal system leading to acute diarrhoea and ultimately death within two weeks. Higher radiation doses lead to failure of the central nervous system, and death typically ensues within two or three days.

Delayed effects include tissue damage manifesting in a few weeks to a few months after exposure. Radiation exposure to a mother carrying a foetus, for example, may cause abortion and organ abnormalities especially of the bones and brain, depending on the time of exposure during embryogenesis; exposed eyes may develop cataract due to loss of transparency, and other delayed effects include thyroid, bone, breast, lung and skin cancers.

The genetic effects of radiation exposure appear in the generation after exposure. Higher incidences of congenital defects, such as abnormalities in bones, the malformation of vital organs including reproductive organs, leukemia, and thyroid and bone cancers, may occur. In the natural environment background radiation can cause genetic mutation, but increased or prolonged exposure to radionuclides such as that due to a radiation accident or leak leads to a further increase in the genetic load of radiation.

At present there are no methods available to reverse this increased genetic load. While it is accepted that radiation and radionuclides can be exploited for useful activities like energy generation, sterilization of medical and food products, diagnostics and radiation therapy of cancer, radiation exposure can also cause a significant problem to human life and the environment, especially the ecosystem. Moreover, increased exposure to radioactive elements can be a threat not only to the present generation but also to future generations and the human race itself.

BACKGROUND RESEARCH

Uranium is one of the most common radionuclide contaminant in groundwater, with leaching of uranium mine tailings resulting in the contamination of soils and aquifers, a process which will likely continue for up to 10,000 years. Many of these contaminated sites require remediation, with the objective of minimising translocation to drinking water systems or biologic receptors via groundwater pathways. Thorium is a relatively immobile element in the environment, but its solubility can be greatly enhanced in acidic, sulphate- and/or organic-rich surface and groundwater systems, where the mobilisation and flushing of thorium from the soil profile can occur in areas of long-term acidification or from colloidal attachment. Thorium isotopes are present in high levels in residues from the processing of uranium ores, where the removal of uranium leads to considerable increases of thorium isotopes, particularly ^{230}Th , which is a member of the ^{238}U decay chain.

Isotope exchange techniques may be employed to study the available or leachable portion of the uranium and thorium bound by surfaces. Consequently, these types of techniques have long been applied in agricultural studies, and enable the plant-available portion of nutrients in a soil system to be identified (often referred to as the “labile pool”). The same concept is also applicable to environmental studies, where the labile pool can be equated with the potentially mobile proportion of the element, which is weakly bound by the mineral surface and is available for leaching. In studies of environmental processes, isotope techniques are often superior to chemical extractions for estimating the mobile fraction because of the operationally-defined nature of extraction techniques.

In 1997, a study was conducted by Clarkson University Remediation Engineers (CURE) in New York to assess options for trapping caesium (^{137}Cs) and strontium (^{90}Sr) present in contaminated groundwater near the Las Cruces site in New Mexico (Clarkson University Remediation Engineers, 1997); the water was contaminated by radionuclides, heavy metals, volatile organic compounds and other inorganic species. The CURE study investigated the performance and cost-effectiveness of numerous alternative strategies that could treat the groundwater, and concluded that the best approach involved the use of material produced from alumina refinery residue. Modified alumina refinery residue (called Bauxsol Raw Material or “BRM”) is used as a primary active ingredient in the manufacture of Virotec’s range of 16 reagents, including Acid B™, Acid B Extra™, Neutra B™, Radium ProActiv™ and Arsenic ProActiv™.

The CURE team designed an innovative system to treat about 500 L/min of water containing between 0 and 3,500 pCi/L of ^{137}Cs and between 0 and 320,000 pCi/L of ^{90}Sr and found the alumina refinery residue was able to trap and bind about 0.2 g strontium and 0.1 g of caesium per kg of refinery residue. The alumina refinery residue also trapped substantial quantities of heavy metals and some other inorganic species (see also McConchie et al., 1996a, 1996b; McConchie, et al., 1999; McConchie and Clark, 1996, 1998; Davies-McConchie et al., 2002; Genç et al., 2003; Genç-Fuhrman et al., 2004a, 2004b, 2004c for more information on the effects of Virotec’s reagents on heavy metals and metalloids).

In similar findings, McPharlin et al. (1994) and Cooper et al. (1995) noted that the addition of alumina refinery residue to sandy farm soils reduced the radioactivity of crops grown on the treated soil because the refinery residue-bound ^{137}Cs prevents uptake by plants; a similar effect would be expected for ^{90}Sr because of its geochemical similarity to caesium (see also Summers et al., 1993); there was no increased uptake of thorium or uranium by plants grown on soil treated with alumina refinery residues.

Early work by McConchie, Clark and Davies-McConchie (2002) furthered these initial studies with the development of BRM and applying it to radioactive elements binding. For example, McConchie, et al. recorded similar ^{137}Cs and ^{90}Sr trapping results for Virotec's reagents using BRM that had been washed in fresh water; BRM has an alkaline earth element deficiency and consequently has an excellent ability to trap and bind elements such as caesium and strontium including the ^{137}Cs and ^{90}Sr radioisotopes, and will hold these elements sufficiently tightly that they are unable to be leached by common groundwater or taken up by plants growing on treated soil.

Furthermore, studies by McConchie and others have shown that the range of Virotec's reagents produced from BRM (see for example McConchie, Clark and Davies-McConchie, 2002; McConchie, Clark, Davies-McConchie and Fergusson, 2002) have a greater ability to trap and bind heavy metals and many other inorganic species than does the original alumina refinery residue. It is also possible to increase the ability of BRM to trap and bind metals and other inorganic species further by activating the material in a manner described by Genç-Fuhrman, et al. (2004a), and its ability to bind phosphate species and neutralise acid have been well documented (Fergusson, 2010).

Treatment Application #1: Radioactive Acid Mine Drainage Treatment

Work conducted at Southern Cross University in Australia showed that Virotec's reagents have an ability to trap and bind radioactive elements (e.g., uranium, thorium and elements produced as a result of the decay of their radioisotopes) that contribute to radioactive contamination of sediments and water systems (Clark, Harrison and Payne, 2009). Trials involving the treatment of acidic metal contaminated water from a uranium mine in Australia showed that both Virotec's Radium Pro Activ™ and Arsenic Pro Activ™ reagents have an ability to remove uranium and thorium, including their radioisotopes, from acidic water.

In a treatment of acidic water (pH = 0.81) from a mine processing plant, the concentration of uranium was reduced from 375 mg/L to <0.1 mg/L and the concentration of thorium from 27.5 mg/L to <0.1 mg/L. In this treatment, water was pre-treated using crushed olivine basalt to raise the pH to about 3.0 and then treated using Radium Pro Activ™ and Arsenic Pro Activ™ reagents, raising the pH to near neutral.



An example of acid mine drainage

TABLE 1: RESULTS FOR RADIOACTIVE ACID MINE DRAINAGE TREATMENT USING VIROMINE™ TECHNOLOGY

Parameter	Before Treatment	After Treatment with ViroMine™ Technology
pH	0.81	6.5
Uranium (mg/L)	375	<0.1
Thorium (mg/L)	27.5	<0.1

Results from the treatment of radioactive acid mine drainage from a mine processing plant.

This study was followed by a more rigorous and thorough investigation. The pH-dependence and reversibility of uranium and thorium binding onto BRM were studied in uptake/leaching experiments by Clark, Harrison and Payne (2011). Natural ^{238}U and ^{232}Th isotopes were contacted with BRM (in order to isolate basic causal factors) in an eight-day loading period (equilibrium pH = 8.5) then leached in pH-dependent experiments, where the pH was decreased from 8.0 to 3.0 over several hours following the addition of exchange isotopes ^{232}U and ^{229}Th . Relative concentrations of the thorium isotope pair (^{232}Th and ^{229}Th) indicate that Th is very strongly bound to BRM, and although at pH 3.0, some desorption is observed ^{232}Th ($\pm 3\%$) and ^{229}Th ($\pm 2.5\%$), released thorium is partially re-adsorbed during the equilibration or stabilisation phase. Other research conducted over many years indicates the stability of Virotec's reagents increases and the reversibility of bound metals decreases over time (Fergusson, 2010).

During the initial equilibration, approximately 50% of the ^{238}U was adsorbed, and a U adsorption maximum occurs between pH 5.0 and pH 6.0, where <0.5% of the U remains in solution. However, at a pH between 5.0 and 3.0, some 60% of the bound U releases, hence the pH range of maximum U retention on BRM is relatively narrow. When equilibrated, BRM releases additional U, suggesting a kinetically controlled desorption linked to mineral dissolution. Plots of U isotope exchange between ^{232}U and ^{238}U are linear, and suggest that U adsorption is somewhat reversible; data for adsorption in mixed systems of U and Th suggest that Th and U compete for similar binding sites on the reagent.

Treatment Application #2: Radioactive Wastewater Treatment

In another unpublished study, phosphogypsum wastewater from several sites in Florida (USA) and Queensland (Australia) with an initial pH of 1.6 was treated using common chemicals to produce marketable by-products and then treated using Virotec's Acid B™ Extra reagent to a pH of 8.4. Phosphogypsum residues from Florida phosphate rock commonly have ^{238}U decay series elements that produce over 1,200 Bq/kg and ^{232}Th decay series elements that produce about 10 Bq/kg (United Nations, 1982); Moroccan rock phosphate typically has ^{238}U decay series elements that produce over 1,100 Bq/kg and ^{232}Th decay series elements that produce over 200 Bq/kg (Paul, et al., 1978); world average superphosphate has ^{232}U decay series



Phosphogypsum from phosphate rock

elements that produce about 450 Bq/kg and ²³²Th decay series elements that produce about 100 Bq/kg (Paul, et al., 1978). The addition of Acid B Extra™ reagent to phosphogypsum-rich wastewater reduced uranium concentrations from 1.3 mg/L to <0.002 mg/L and thorium concentrations from 0.1 mg/L to <0.002 mg/L.

TABLE 2: RESULTS FOR RADIOACTIVE WASTEWATER TREATMENT USING VIROMINE™ TECHNOLOGY

Parameter	Before Treatment	After Treatment with ViroMine™ Technology
Phosphogypsum Wastewater		
Uranium (mg/L)	1.3	<0.002
Thorium (mg/L)	0.1	<0.002
Berkeley Pit Wastewater		
pH	1.6	6.5
Uranium (µ/L)	760	1.05
Thorium (µ/L)	127	0.03
Beryllium (µ/L)	80	<0.1

Results from the treatment of radioactive wastewater at two sites in the U.S.

These findings related to the trapping and binding of uranium and thorium in phosphogypsum-contaminated wastewater were also independently confirmed by the U.S. Environmental Protection Agency on mine wastewater from the Superfund site at Berkeley Pit in Butte, Montana using Virotec's Neutra B™ reagent. In this project, the uranium content of open-cut pit mine wastewater was reduced from 760 µg/L to 1.05 µg/L and thorium concentrations were reduced from 127 µg/L to 0.03 µg/L; in the same study the concentration of beryllium (Be) was reduced from 80 µg/L to not detected (<0.1 µg/L).

Treatment Application #3: Mine Wastewater Treatment

At one of world's largest uranium and copper mines, Virotec conducted preliminary work to measure the degree to which Virotec's ViroMine™ Technology could treat mine process water and ponded wastewater contaminated with uranium and other elements, including radioactive manganese (Mn), water turbidity, ammonia (NH₃) and acidity. The focus of the initial treatment was on total uranium, for which there was a treatment target of 6.0 mg/L.



The Berkeley Mine Pit

TABLE 3: RESULTS FOR RADIOACTIVE PROCESS WATER AND PONDED WASTEWATER TREATMENT USING VIROMINE™ TECHNOLOGY

Parameter	Before Treatment	After Treatment with ViroMine™ Technology
Process Water		
pH	3.5	7.0
Total Uranium (mg/L)	40.3	0.89
Ponded Wastewater		
pH	7.2	7.0
Total Uranium (mg/L)	4.59	1.2

Results from the treatment of radioactive process water and ponded wastewater at a uranium mine.

Based on an initial characterization study, it was deemed that the uranium present in the ponded effluent was as a uranium-carbonate complex, with minor uranium-ammonia complexes. For the process water effluent uranium-ammonia complexes dominated, with little to no carbonate complexes. Degradation of these complexes was determined to be required to produce effective treatment of the effluents, where releasing both uranium and ammonia into solution allows effective treatment of the total contaminant load by Virotec's Acid B™ reagent.

A variety of chemical agents were trialled as pre-treatments in combination with Acid B™ reagent to determine the potential effect of breaking down the various complexes, including hydrogen peroxide (H₂O₂), sodium sulphide (Na₂S), iron sulphate (FeSO₄), and magnesium oxide (MgO). For example, the use of FeSO₄ precipitated uranium sulphates, ammonium sulphates, and uranium-ammonium-sulphates, reduced uranium from hexavalent to tetravalent species, and reduced turbidity by the aggregation of colloidal particles. As a result of this pre-treatment, residual iron was bound to the Acid B™ reagent. Iron sulphate salt (FeSO₄.7H₂O) was dosed at 1.0 g/L, mixed for one hour, then left for three hours to allow for reaction and precipitation; Acid B™ was then dosed at 5.0 g/L, mixed for one hour and left to settle for three hours before filtration (0.45 µm) and analysis. In both cases, the treated total uranium levels were well below the treatment target of 6.0 mg/L, and pH was within normal limits.

Treatment Application #4: Radioactive Materials Shielding

Preliminary work conducted by researchers at Southern Cross University in Australia using MicroShield and a theoretical radioactive source to determine the potential of BRM to shield radioactive elements found a concrete thickness of 85 cm (34") reduces exposure from the radioactive source to an acceptable level (Maher, Clark, Harrison and Payne, 2009). However, with the addition of Virotec's BRM to the concrete shield, the thickness can be reduced to between 64 cm (26") and 73 cm (29"), up to a reduction of 25%, depending on the ratio of BRM to concrete.

In this study, shielding of the following radioactive elements was modelled: Barium (^{137m}Ba, 1,830 Ci); Caesium (¹³⁴Cs, 15.3 Ci; ¹³⁷Cs, 1,940 Ci); Europium (¹⁵⁵Eu, 3.90 Ci); Niobium (⁹⁵Nb, 465 Ci; ^{95m}Nb, 1.84 Ci); Promethium (¹⁴⁷Pm, 107 Ci); Rhodium (^{103m}Rh, 2.5 Ci; ¹⁰⁶Rh, 52.6 Ci); Ruthenium (¹⁰³Ru, 2.5 Ci; ¹⁰⁶Ru, 5.3 Ci); Antimony (¹²⁵Sb, 9.9 Ci); Strontium (⁸⁹Sr, 6.6 Ci; ⁹⁰Sr, 92 Ci); Tellurium (^{125m}Te, 2.4 Ci; ¹²⁷Te, 2.2 Ci; ^{127m}Te, 2.2 Ci); Yttrilite (⁹⁰Y, 92 Ci); ⁹¹Y, 29 Ci); and Zirconium (⁹⁵Zr, 217 Ci).

Data also indicated that the addition of small amounts of higher density shielding materials (in particular 20% Fe, 15% Pb and <5% U) into the BRM reduces the thickness of the shield to around 42 cm (17”) or about half the thickness of concrete. Thus the study indicated that BRM has potential in radiation shielding and suggested that further work on the shielding properties of BRM along with other blended materials was warranted. These findings are consistent with work conducted by Barbhuiya, et al. (in press) which show that a 15% inclusion of BRM into a “standard construction concrete” as a sand replacement agent increases the density of concrete to 2.4 g/cm by pore filling, without affecting concrete durability.

Treatment Application #5: Radium in Drinking Water

Radium (Ra) is an alkaline earth mineral found in trace amounts in all uranium-bearing ores. Almost all radium in drinking water supplies occurs naturally, although in some instances anthropogenic activities (e.g. mining, phosphate production, and agriculture) can lead to significant inputs of radium. The relative concentrations of natural Ra in drinking water result from the origin of the water, the geology that it passes through and is formed within (for example, granite enclosed aquifers), including factors such as indigenous soil type and pH. Moreover, the chemical form in which Ra is present in the soil and its concentrations also determine how effectively Ra becomes incorporated into groundwater.

Given that Ra is chemically similar to calcium, inhalation, ingestion or body exposure to Ra has the potential to cause harm as it replaces Ca in human tissue. Accordingly Ra has been implicated as a major cause of bone cancer and other disorders; consequently Ra-rich water in the U.S. usually undergoes potabilization (i.e., chemical treatment) before being considered suitable for human consumption. Several areas of the U.S. have higher rates of these disorders, which are linked to elevated Ra concentrations in drinking water. For example, many areas of Missouri, New England and South Carolina have groundwater Ra concentrations in groundwater that exceed the U.S. EPA guidelines for safe human consumption of 0.185 Bq/L (5.0 pCi/L).



A uranium mine

In general, most water potabilization plants utilize a series of chemical reagents suited to the particular parameters of the water being treated. The most commonly used coagulants are based on iron or aluminium, which are well documented in removing Ra from water. Other technologies that have been evaluated or used for the elimination of Ra from drinking water include reverse osmosis, lime softening, cation exchange, MnO₂-coated acrylic fibre filters, and BaSO₄-impregnated alumina. Regardless of the method, all treatment processes produce either a waste solid byproduct (i.e., sludge) or liquid backwash containing the removed Ra, and these treatment by-products must be disposed of appropriately, usually at high cost.

Radium removal from drinking water using Radium Pro Activ™ was investigated (Clark, Akhurst and Fergusson, in press) for groundwater extracted in Missouri, USA. The application of Radium Pro Activ™ dramatically reduced gross alpha and combined ^{226/228}radium concentrations from 0.955 and 0.66 Bq/L (or 25.8

and 17.84 pCi/L respectively) to below detection limits (0.037 Bq/L or 1.0 pCi/L). Column breakthrough occurs at 0.555 Bq/L for gross alpha and 0.185 Bq/L for combined $^{226/228}\text{Ra}$ (15 and 5.0 pCi/L, which are the U.S. EPA's minimum concentration limits) at 40 and 54 day run-times. At 84 days, the Radium Pro Activ™ media continues to remove 24.3% of raw water gross alpha and 39.7% of the combined $^{226/228}\text{Ra}$.

Although treated drinking water had an initial water pH of 10.9, which is outside U.S. EPA regulations of 6.5-8.5, pH levels were mitigated by acid injection, raw water blending, and/or by the control of contact times in order for treated water to conform to guidelines. Radium Pro Activ™ simultaneously removed other potentially hazardous trace elements, including Cu, Zn and Fe, to extremely low concentrations. TCLP testing of the spent Radium Pro Activ™ media suggested that metals are bound tightly such that it is non-hazardous, permitting cost-effective disposal in Class D municipal landfills without special confinement or storage. Consequently, Radium Pro Activ™ may be utilized as an alternative adsorbent for treating Ra-contaminated groundwater.



The filter installation at Gilbert-Summit

TABLE 4: RESULTS FOR RADIOACTIVE DRINKING WATER TREATMENT USING VIROFLOW™ TECHNOLOGY

Parameter	Before Treatment	After Treatment with ViroFlow™ Technology
Radium Gross Alpha (pCi/L)	25.8	<1.0
Combined $^{226/228}$ Radium (pCi/L)	17.8	<1.0

Results from the treatment of radioactive drinking water at a water processing facility in the USA.

These findings were replicated at the Gilbert Summit Rural Water District, in South Carolina, USA. A project was conducted over 42 days to determine the radium removal capacity of Radium Pro Activ™. A total of 53,830 gallons of radium contaminated water was passed through the treatment unit and a total of 943,061 pCi was removed from the water equating to approximately 65 pCi/g of reagent. The regulatory limit for disposal of the spent reagent was 200 pCi/g; of this amount, only 17.8 pCi/L was able to be leached from the spent reagent.

The Gilbert Summit Rural Water District was issued a “Radioactive Material License” by the state of South Carolina for the quantity of Naturally Occurring Radioactive Material (NORM) and Technically Enhanced Naturally Occurring Radioactive Material (TENORM) permissible at their site. The license required that testing be performed to prove that radiation levels were below the established limits of 200 pCi/g and that a contaminant professional review and submit the data to the state and a “Subclass D” landfill to obtain a “Disposal Permit”.

The limits in South Carolina are set by the state environmental protection department. Each individual landfill has the authority to accept or decline shipment of the material, regardless of the waste stream meeting the predetermined limit of 200 pCi/g. No special requirements or permits were required to transport the material, as the spent media was deemed “Non-Hazardous, Regulated” by definition of South Carolina Codes.

CONCLUSION

Based on the above data and applications, it appears that Virotec’s reagents have the ability to trap and bind radioisotopes and to reduce the concentrations of these radioactive elements in treated water to low levels. While large-scale, industrial applications of this treatment modality have not been documented thoroughly, there is enough evidence to suggest that Virotec’s reagents may have the ability to effectively treat the impact of manmade radioactive elements entering the environment and the human food-chain.

Given the ability of Virotec’s reagents to also remove a wide range of trace metals and metalloids from contaminated water, soil, and industrial solids, further applications should be carried out to determine the scope of this treatment and the reversibility of binding of radioactive elements using Virotec’s various technologies.

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