

**AnyWay Natural Soil Stabilizer (ANSS)
and
its Effect on the Environment**

1.0	Introduction	3
2.0	Background	4
	2.1 Chemical impacts	4
	2.2 Physical impacts	4
	2.2.1 Excavation, material acquisition and dumping	4
	2.2.2 Erosion	5
	2.2.3 Noise	5
	2.2.4 Aesthetic pollution	5
	2.2.5 Water pollution	5
3.0	Experimental	5
	3.1 ANSS	5
	3.2 TCLP	5
	3.3 Modified leaching characterization	6
	3.3.1 Sample preparation	6
4.0	Results and Discussion	6
	4.1 TCLP results	6
	4.2 TCLP discussion	7
	4.3 Modified leaching results	8
	4.4 Modified leaching discussion	9
	4.4.1 pH dependent solubility	9
5.0	Conclusion	10

ANSS and its effect on the environment

This document serves to highlight the various kinds of impacts that are possible when considering road construction while assessing the potential physical and chemical impacts with respect to ANSS. Assessment of the environmental fate of ANSS was achieved through conducting TCLP experiments under acidic and basic mediums, as well as modified leaching experiments. TCLP predicts the solubility (mobility) of specific potential toxic substances under specific testing conditions, and a product that passes TCLP testing is regarded as being non-toxic.

Of the heavy metals analyzed by TCLP, all are immobilized at high pH values and pose little threat of leaching from an ANSS stabilized system. Leaching aside, given the fact that there is no addition of any heavy metal to ANSS as a catalyst or additive, and that the compounds mixed to form ANSS are natural in origin, there can be no threat of contamination into the soil or groundwater as the levels in the product in the first place are negligible.

All analyzed elements under modified leaching experiments are lower than the TCLP regulatory levels, even for leaching experiments with ANSS powder. Leachate from ANSS is lower than US and Canadian drinking water standards, which is a testament to the almost un-existing environmental threat of ANSS. TCLP and modified leaching experiment results indicate that even if leaching was to occur, which is extremely unlikely, the leachate would be of such a low level of threat that it would not affect any surrounding body of water (groundwater) or cause toxicity to the surrounding ecosystem. Due to ANSS's non-toxicity it was awarded the Green label by the Ministry of the Environment and the Standards Institution of Israel, an award that highlights AnyWay's commitment to protecting the quality of the environment.

1.0 Introduction

Our natural environment is increasingly becoming a major factor to consider when venturing into any new or existing road building project. This is particularly relevant when soil stabilization is considered, as a foreign substance, the stabilizer, is added to a medium in which the potential for leaching is high. Chemical reactivity and leaching are not the only environmental issues to consider, as road construction requires large amounts of earthworks and the potential for environmental impacts on a physical level are therefore high. It is for these physical and chemical reasons that AnyWay places a very high level of commitment on ensuring that its product is not a threat to the environment under any foreseeable circumstance while minimizing the potential for physical impacts.

There are in essence two types of environmental impacts; chemical and physical. Chemical impacts include the effects that addition of a chemical, whether it is solid or liquid, natural or synthesized, has on the environment (micro and macro) to which an addition has been made.

Chemical mobility and toxicity assessment are important in determining its fate in the environment.

Physical impacts revolve around those aspects in which application or construction affects the natural landscape. This can be as simple as walking through a fragile ecosystem or as intensive as clear cutting a forest, or in the case of road construction, removal and disposal of undesirable soil types.

There is a link between chemical and physical impacts, however their relationship is such that each aspect can be dealt with individually without compromising the understanding of the related subject. This document serves to highlight the various kinds of impacts that are possible when considering road construction while assessing the potential physical and chemical impacts with respect to ANSS.

2.0 Background

2.1 Chemical impacts

Chemical impacts are those that are a direct result of a foreign substance, a chemical, acting on the functioning of the local environment. Assessment of a chemical impact is the essence of environmental chemistry, the study of natural and synthesized substances in the environment, including the detection, monitoring, transport, and chemical transformation of chemical substances in air, water, and soil.

Chemical impacts are assessed using analytical techniques to determine parameters that can be compared to qualitatively and quantitatively researched databases. The chemical parameters are used to assess toxicity, mobility, longevity and reactivity in the potentially contaminated or already contaminated medium. The study of environmental chemistry was first created as a result of humankind's impact (mainly negative) on our natural environment, as our actions were without consideration of their consequences. Now, environmental chemistry has evolved into two broad categories; remediation and assessment. It is this latter aspect that includes environmental risk assessment, in which the nature of any addition or alterations to our natural ecosystem is known in advance of its implementation.

ANSS has undergone constant international testing and regulation to provide technical literature as to its environmental fate. Much of the reasoning behind repeat testing, despite international acceptance of EPA guidelines, is that each country to which the product is to be applied places such a high level on regard to the environment that it wants tests to be conducted on its own regulatory standard (even if it is lower than that of the EPA). Alternatively, many countries want testing to be carried out in a lab within their country, despite following the same standard that has already been assessed. This

type of repeat testing and continued certification only helps to convey AnyWay's environmental commitment to assuring that ANSS is an environmentally friendly product for use in soil stabilization.

2.2 Physical impacts

Physical impacts are non-chemical and include those that are caused by physical or biological disturbances. Non-chemical stressors identified by SETAC (The Society of Environmental Toxicology and Chemistry) include ionizing radiation, heat, noise, environmental disturbances (habitat alteration, including changes to biochemical cycling, biodiversity and loss of endangered species), physical change to water (siltation and flow, interrupted surface or subsurface drainage, drop in aquifer levels), physical changes to soil (erosion and soil loss), regional climatic change, and species change (alterations in composition or total diversity). These impacts are not distinct, but overlap and interact.

Building of a road impacts the physical environment in many ways; however they can be significantly reduced or even altogether avoided through the use of ANSS. The major physical issues to be considered include excavation and dumping, material acquisition, erosion, noise and vibration, aesthetics, and alterations to water.

2.2.1 Excavation, material acquisition and dumping

Traditional road construction requires extensive earth movements from the site of materials deemed as deleterious due to their poor engineering characteristics.

Soil stabilization with ANSS uses the in-situ soil for stabilization, therefore the need for removing the soil from the site of construction is eliminated.

Further, a soil that would have been removed requires dumping and rehabilitation to the site in which the waste material has been dumped. Stabilization of in-situ soils

eliminates the cost and physical impact created by excavation and dumping.

Removal of unsuitable soils requires that they be replaced with a suitable soil that has the engineering characteristics suited to the road design. The acquired soil is extracted from pits as close to the road as possible to minimize the haulage costs. The use of soil from borrow pits for road production will require closure and rehabilitation of the borrow-pit area. ANSS can increase the in-situ soil to the required engineering design standard and thus a material acquisition is almost exclusively eliminated.

2.2.2 Erosion

Most of the earthworks that are associated with road construction can contribute to soil erosion, especially if no preventive measures are taken. Reduced earthworks directly translate to a potential reduction in erosion.

2.2.3 Noise

It is well known that large vehicles in general generate more noise than smaller vehicles, especially if these vehicles are heavily loaded and slow moving as they are during typical road construction. The use of heavy vehicles is minimized through the use of ANSS as the need for hauling material to or away from the site is not required. The only heavy vehicles used are those that are required for road construction itself.

2.2.4 Aesthetic pollution

Typical aesthetic pollution results from improper disposal of excess materials removed from the road building site. As material is being removed from the site dust is created, which stains the surrounding vegetation cover. Reduction in the amount of haulage to and from the application site will limit the amount of dust and resultant aesthetic pollution.

2.2.5 Water pollution

The influence of roads on water pollution is primarily through erosion of soil into watercourses or leaching from the pavement layer. Often is the case in which road construction takes place in areas where development has yet to be established. In such areas, water can be a premium concern and crucial importance to the surrounding cultures and agricultural practices.

Due to the reduction in large earthworks these concerns can be abated.

When considering soil stabilization, chemical impacts are of larger concern due to the fact that an addition of a foreign substance to a natural in-situ soil is being made. Under such usage the full environmental fate of the product (the soil stabilizer) needs to be known. The remainder of this document will focus on the chemical impacts and environmental fate of ANSS Natural Soil Stabilizer.

3.0 Experimental

3.1 ANSS

ANSS is an inorganic hydraulic powder of regulated composition. Samples of newly produced powder were used under all testing circumstances and were checked for quality assurance chemically and physically prior to use.

3.2 Toxicity characteristic leaching potential

TCLP assessment was performed following the method outlined in Test Methods for Evaluating Solid Wastes, SW-846 Method 311, July 1992. ANSS was determined to be composed of 100% solids and no fraction of the solid required particle size reduction. Fluid #2 was used as determined by the outlined method for extraction fluid determination. The dilute acetic acid (CH_3COOH) solution was adjusted to pH 2.88. A volume of 200 ml of CH_3COOH

was added to 10g of ANSS in an extraction vessel and rotated for 18 hours at 30 rpm. The temperature was kept constant at 23 °C during agitation. Solutions were filtered through 0.45 µm filter paper and diluted to the appropriate electro-conductivity ($EC < 100 \mu\text{S}/\text{cm}$) for analysis with ICP-MS (inductively coupled plasma - mass spectrometry).

Due to the highly basic nature of ANSS, toxicity characteristics were assessed using basic extraction in addition to the standard CH_3COOH extraction. TCLP procedures were followed for the basic extraction as well, but substitution of a pH 10.33 carbonate solution was made for the CH_3COOH .

3.3 Modified leaching characterization

ANSS is a hydraulic substance, in that its reaction products after hydration differ in structure and reactivity compared to the starting material. ANSS hydrates to form a dense unreactive solid matrix of reduced solubility. It is added to a soil at concentrations ranging from 1 - 6% of maximum dry density (MDD), therefore assessment of its leaching potential cannot be done without consideration of the concentrations to which it is added to the soil and the reduced reactivity of the reaction products. Additionally, the matrix that is formed has a significantly reduced surface area, therefore the extracting fluid (whether it is acid, neutral or basic) will not have the same extracting potential.

3. Sample preparation

Tests were conducted on three (3) samples containing ANSS.

Sample A: 143g of ANSS was mixed at a w/c ratio of 0.4 at room temperature and placed in a sealed plastic tube (33 cm x 66 cm; $A = 56.5 \text{ cm}^3$) and cured for 7 days. A longer curing period was not selected due to the higher leaching rate that would be obtainable at a lower curing period than a longer period and thus a “worst case” scenario would be represented.

Sample B: a clayey sandy gravel classified under AASHTO as being A.2-4 was stabilized with 5% ANSS (5.72g) based on MDD and mixed to OMC and compacted in a plastic tube (33 cm x 66 cm; $A = 56.5 \text{ cm}^3$). The sample was cured for 7 days.

Sample C: a fresh un-stabilized powder sample of ANSS with the same mass (143g) as was used to produce sample A (143 g).

Each sample was leached in 200 ml of de-ionized water at room temperature for three hours and stirred at 20 rpm. The leachate was measured for pH and EC before being filtered through a 0.45 µm filter. The filtered samples were diluted to an $EC < 100 \mu\text{S}/\text{cm}$ and analyzed for major ions by IC (ion chromatography) and trace element concentration by ICP-MS.

4.0 Results and Discussion

4.1 TCLP results

TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multiple phase samples. The solid phase is extracted with an amount of extraction fluid (acetic acid) equal to 20 times the weight of the solid.

Following extraction the liquid extract is separated from the solid phase and processed. The toxicity characteristic of a waste material is established by determining the levels of 8 heavy metals and as presented in Table 1; arsenic (As),

barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se), and silver (Ag).

Carbonate leaching (basic solution) results are presented in Table 1. Analysis was conducted on the same 8 heavy metals that were outlined by the EPA as having acute toxic effects. Comparison of leaching under acidic and basic conditions is important due to the change in soil pH that is possible when considering ANSS soil stabilization.

Table 1. Acidic and basic TCLP results for ANSS (Chemiricerche, 1999)

Contaminant	Acetic Acid (mg/l)	Carbonate (mg/l)
As	<0.005	<0.005
Ba	0.928	0.195
Cd	<0.005	<0.005
Cr	<0.05	0.158
Pb	<0.01	<0.01
Hg	0.002	0.005
Se	0.029	<0.005
Ag	bdl	bdl

* bdl = below detection limit

4.2 TCLP discussion

From the standpoint of potential hazards to human health and the environment, an extended list of “priority metals” has been established by the EPA. They include As, Ba, Cd, Cr, Pb, Hg, Se, and Ag. The regulatory level of each heavy metal is presented in Table 2.

Acidic leaching is used to assess the mobility of heavy metals, as heavy metals are generally more mobile under acidic conditions. Under basic conditions heavy metals tend to form insoluble hydroxides (OH) or oxyhydroxides

(OOH). The TCLP results for samples extracted with acetic acid (acidic) and carbonate (basic) illustrate that ANSS is classified as non-toxic. All concentrations are well below the standard regulatory levels designated by the EPA (Table 2).

When comparing the results of heavy metals extracted under acidic and basic conditions, it is observed that they are similar in concentration despite the elements differing behavior under the two conditions. This is most likely due to the extremely low concentration in both samples (acidic and basic), so low as not to be able to see an appreciable difference (near the detection limits for the element). The only marginal difference that can be seen is for barium and chromium (Table 1).

At high pH levels chromium will be oxidized to the chromate ion (CrO_4^-) which has a greater mobility than the Cr^{3+} cation that is predominant under acidic conditions. Cr^{3+} chemisorbs on oxides and silicates, both of which are highly available in ANSS. Despite the difference in concentration under the varying conditions, chromium is still well below the 5 ppm value set under the TCLP standard.

Barium has a high affinity for substitution onto silicate structures at low pH values. The inorganic nature of ANSS and presence of a complex framework presents an abundance of sites for Ba^{2+} to adsorb onto, which accounts for the difference in concentration at varying pH values.

While TCLP is a recognized testing procedure for toxicity assessment, it does have limitations. The motive behind creating the TCLP was for specific use in assessing the level of contamination that hazardous waste would have on groundwater if it was disposed of in a municipal landfill. Such a test represents the “worst case” scenario and it may not accurately reflect the in situ environment. In essence, TCLP predicts the solubility (mobility) of specific potential toxic substances under specific testing conditions (acidic). Therefore, a product that passes TCLP testing is regarded as being non-toxic (move to beginning) even though it may

exhibit toxic levels under different testing conditions, or the product may be deemed toxic under the testing conditions but non-toxic under the conditions to which it will be contained.

Table 2. Maximum concentration of contaminants for TCLP and EPA National Primary Drinking Water Standard.

Contaminant	TCLP Regulatory level (mg/l)	Drinking water MCL* (mg/l)
As	5	0.01
Ba	100	2
Cd	1	0.005
Cr	5	0.1
Pb	5	0.015
Hg	0.2	0.002
Se	1	0.05
Ag	5	-

*MCL = maximum contaminant level

In general, TCLP testing with ANSS should be used only as part of a more elaborate and relevant leaching appraisal even though ANSS is well below the TCLP requirements.

4.3 Modified leaching results

Modified leaching tests were conducted to complement TCLP results and provide a more substantial and comprehensive assessment as to ANSS's fate once applied to a soil. Soils are extremely variable with respect to their chemical, physical and structural properties, therefore the modified leaching tests have been conducted in such a way that the worst case scenario is portrayed. Leaching results of heavy metals that are associated with toxicity are displayed in Table 3. Drinking water quality

guidelines from Health Canada are also presented as a reference.

The concentration of all elements other than Co and Pb are higher for Sample C than for the other samples.

Sample C is un-reacted powder of ANSS and will, upon contact with water, start to hydrate. The much higher specific surface area of a powder contributes greatly to the concentration in solution and the relatively high results of heavy metals in solution are not unexpected.

Samples A and B are cured samples, that is, they have been previously hydrated and solidified. The development of a solid cylinder with an extensive interparticle matrix reduces the capillary and pore spaces of the solid, which reduces the surface with which dissolution and leaching can occur. Further, ANSS has formed sparingly soluble and irreversible reaction products through the hydration process. Both samples A and B are more realistic examples of the potential leaching than that of Sample C, as unreacted ANSS is never presented with the opportunity to leach.

The pH of the leachate solutions is very basic for all samples, especially for the cured cylinder of ANSS and the pure powder. This result is expected, as unreacted ANSS has a greater influence than reacted ANSS, which in turn has a smaller effect on pH as concentrations decrease (as is the case with sample B).

While modified leaching experiments are not identical to the TCLP procedure, comparison of results to those of the TCLP regulatory standards is warranted. All analyzed elements under all modified leaching experiments are lower than the TCLP regulatory levels, even for leaching experiments with ANSS powder. Of higher relevance and comparability is the concentration of high risk transition metals contained in ANSS leachate with the EPA's Primary Drinking Water Standards (Table 2) and Health Canada's drinking water standards (Table 3). Samples A and B have

concentrations of inorganic chemicals lower than both national standards for all elements, while all elements except Cr and Cd for Sample C are lower.

Drinking water standards have been outlined in such a way as to present the lowest level at which a known cause is known for human toxicity. Such levels are extremely low and differ with respect to the allowable concentration that can be leached (TCLP, Table 2). The fact that leachate from ANSS is lower than US and Canadian drinking water standards is a testament to the almost non-existent environmental threat of ANSS.

4.4 Modified leaching discussion

A comparison of the leachable fraction of heavy metals from ANSS and those commonly found in water bodies, as well as those in the earth's crust, are presented in Table 4. The concentrations in Sample B, which is the only sample representative of an actual leaching potential, are comparable and sometimes lower (As, Cu, Mn, Pb) to those found within the oceans and rivers of the world.

The earth's crust also contains high concentrations of transition elements in the solid phase.

The concentrations of trace elements in natural systems are often much lower than are encountered in experimental methods to assess their mobility. The most common reasons for the low concentrations is adsorption of the element onto a solid phase and coprecipitation. Adsorption occurs when a dissolved ion becomes attached to the surface of a preexisting solid substrate, such as a clay particle or silicate molecules present in ANSS. Coprecipitation occurs when a dissolved species is incorporated as a minor component in a solid phase as that phase itself is precipitated. Coprecipitation and adsorption of heavy metals onto clay surfaces and incorporation into the ANSS matrix are important sinks for heavy metals.

4.4.1 pH dependent solubility

The pH of natural waters can range significantly from one source to another, however this deviation is limited for the most part between pH 4 and pH 7. Thus, pH values of 12.45, 10.43 and 8.87 are high enough to be classified as unnatural. Such high pH values of the soil solution play a very important role when considering leaching and solubility of heavy metals.

Table 3. Heavy metal data (mg/l = part per million) by ICP-MS for leaching experiments on ANSS.

Sample	pH	Ec (mS/cm)	As	Cd	Co	Cr	Cu	Mn	Ni	Pb	Se	Zn
A	10.43	0.776	0.0004	bdl	0.00006	0.008	0.0023	0.0040	0.0037	bdl	0.0022	0.0072
B	8.87	0.372	0.0006	0.0002	0.00006	0.0035	0.0226	0.0041	0.0072	0.0006	0.0005	0.0239
C	12.45	10.93	0.00090	0.00010	bdl	0.559	0.451	0.036	0.037	bdl	0.036	0.572
HC‡	6.5-8.5		0.025	0.005	-	0.05	1.0	0.05	-	0.01	0.01	5.0

*bdl = below detection limit

‡HC = Health Canada, Summary of Guidelines for Canadian Drinking Water Standards, April 2002.

Table 4. Typical ranges of heavy metal concentrations in the earth's crust (mg/kg; ppm) and concentrations in streams and the ocean ($\mu\text{g}/\text{kg}$; ppb) compared to the concentration contained in leachate ($\mu\text{g}/\text{kg}$; ppb) from ANSS Natural Soil Stabilizer.

	Earth's crust	Stream	Ocean	Sample B
Cr	100	1	0.2	3.5
Mn	950	8	0.2	4.1
Co	20	0.2	0.05	0.6
Ni	80	2	0.5	7.2
Cu	50	30	0.5	22.6
Zn	75	0.1	2	23.9
As	1.5	2	3	0.57
Se	0.05	0.2	0.1	0.45
Cd	0.1	-	0.05	0.24
Pb	14	1	0.03	0.57

***bdl = below detection limit**

Solubilities of heavy metals at high pH values are generally limited by the solubility of a carbonate or oxide/hydroxide. It is rare for pH values in nature to be sufficiently high for such species to be important, however

through the addition of ANSS, which raises the pH, these species do play a very important role.

Manganese will decrease in solubility at pH values greater than 6, as it will form insoluble oxide and silicate precipitates. Cobalt will co-precipitate with manganese and at raised pH levels it will chemisorb on oxides and silicates, both of which are present at high concentrations in ANSS stabilized systems. Nickel is the smallest divalent transition metal and therefore fits well into octahedral sites of clay particles and aluminosilicates. It has an affinity for

Mn and Fe oxides and chemisorbs strongly as pH is increased in the soil solution. Its mobility in any system is significantly limited. Copper, Pb and Zn are classified as chalcophiles, they form insoluble sulfide minerals in reducing environments. At pH levels above 6 the chalcophilic transition metals will form insoluble hydroxide precipitates.

Of the heavy metals analyzed, all are immobilized at high pH values and pose little threat of leaching from the system, especially after stabilization has occurred.

Leaching aside, given the fact that there is no addition of any heavy metal to ANSS as a catalyst or additive, and that the compounds mixed to form ANSS are natural in origin, there can be no threat of contamination into the soil or groundwater as the levels in the product in the first place are negligible.

5.0 Conclusion

Leaching tests performed on ANSS have shown that there is no risk involved or contamination of surrounding water bodies and soils from heavy metal leaching. As there is no addition to ANSS of heavy metals there is no risk of contamination to the surrounding soils, and in fact with the increased pH of the stabilized matrix the risk of movement of heavy metals from the material is lowered even further.

For TCLP testing under acidic and basic all elements are under the regulatory level set by the EPA. Additionally, modified leaching experiments, which were designed to provide a more comprehensive approach to the composition of any leachate that does occur, indicate that the concentration for all elements and all samples is below the TCLP guidelines. The concentration of transition elements in leachate from Samples A and B is below the primary drinking water standards, while Sample C is only slightly above for Co and Pb; however the high pH medium of the soil solution and the nature of the soil

environment will cause these metals to form insoluble carbonates and hydroxides.

Addition of ANSS is followed by water addition. The amount of water that is added to the system is not sufficient to leach through the stabilized layer, as it is a calculated quantity of water required to bring about the maximum density during compaction. Further, addition of water to the soil starts the hydration process, which results in a substantial amount of H₂O molecules being incorporated into the new crystal structure.

Much of the leaching assessment is done without consideration of the fact that only one dimension (the surface) of the stabilized layer is open to contact with water, unlike leaching test in which three dimensions are available. In other words, an ANSS stabilized layer is confined/contained system, whereas leaching test are unconfined the Penetration of water on a one dimensional framework will decrease the values obtained for three dimensional leaching tests even further.

Heavy metals that would be contained in the soil prior to addition of ANSS would be immobilized as well through the increased pH of the soil environment. The amount of heavy metals to leach through a stabilized system (if leaching could occur) would most likely be less than that of the leached unstabilized in-situ soil.

Leaching tests, both modified and international, highlight the low environmental threat that ANSS poses. Results indicate that even if leaching was to occur, which is extremely unlikely, the leachate would be of such a low level of threat that it would not affect any surrounding body of water (groundwater) or cause toxicity to the surrounding ecosystem.

Due to ANSS's non-toxicity it was awarded the Green label from the Ministry of the Environment and the Standards Institute of Israel, an award that highlights AnyWay's commitment to protecting the quality of the environment.