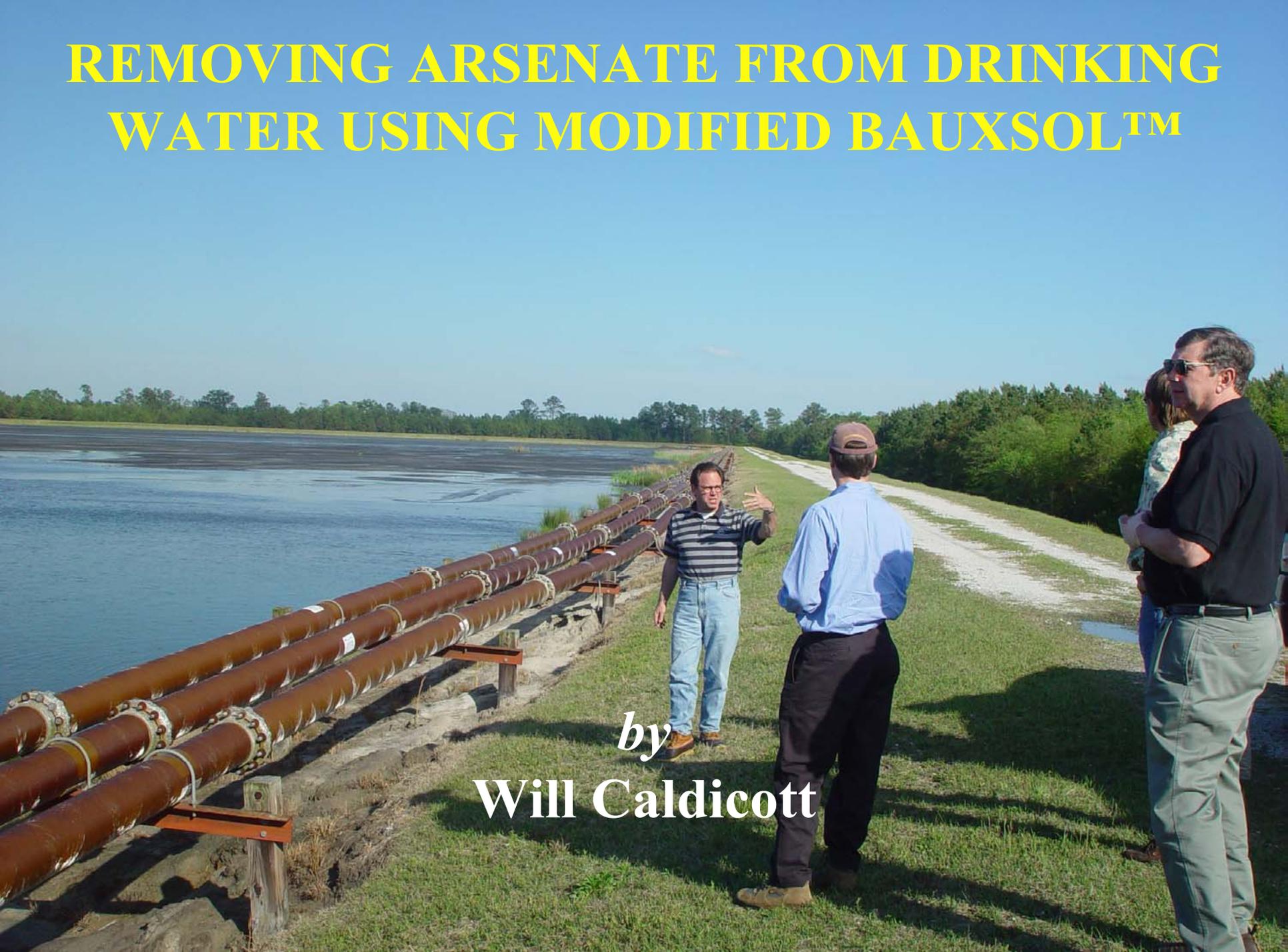


REMOVING ARSENATE FROM DRINKING WATER USING MODIFIED BAUXSOL™



by

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WHAT IS BAUXSOL™?

Bauxsol™ is the mineral cocktail prepared by the Basecon™ process as follows:

- 1. Add seawater, or evaporatively concentrated seawater, or Ca- and Mg-rich brines, or crystalline CaCl_2 and MgCl_2 , or some combination of these alternatives, to caustic bauxite refinery residues until the liquid phase has a pH of 9.0 - 9.5 and an alkalinity of < 300 mg/L (these values should remain stable for at least 30 mins).**
- 2. Separate the solid and liquid fractions** by settling and separate (decant, centrifuge, or filter) off the liquid phase.
- 3. Add acid** to the liquid fraction until the pH is < 9.0 and the alkalinity is < 200 mg/L.
- 4. Discharge the liquid** to the sea or transfer it to an evaporating pond for salt recovery.
- 5. Wholly or partly dry the solid fraction,** or retain it as a slurry or in some other form for reuse or storage as required.

The Bauxsol™ can be further modified to suit particular applications by acid treatment to remove reactive alkalinity, washing to remove soluble salts, the addition of chemical additives, pelletization, or any combination of these treatments.

SOME PROPERTIES OF RAW BAUXSOL™

1. Red - red brown mineral cocktail,
2. 5 : 1 reaction pH of 8.0 - 9.0 with water,
3. Neutralises 3.5 - 7.5 moles of acid/kg Bauxsol™ (14 moles/kg if the pH is < 5); the ANC can be further increased using blends,
4. Traps & binds > 1,500 meq metals/kg Bauxsol™ and several anions (e.g. phosphate, arsenate, cyanide), by mechanisms that include: precipitation of low solubility neoformational minerals, isomorphous substitution, solid state diffusion and adsorption,
5. Produces a stable sediment and not a sludge,
6. Although > 80% of Bauxsol™ particles are < 10 µm, it is largely insoluble and non-dispersive in water

Bauxsol™ Mineralogy

Major minerals in decreasing order of abundance

Hematite Fe_2O_3

Boehmite $\gamma\text{-AlOOH}$

Gibbsite $\text{Al}(\text{OH})_3$

Sodalite $\text{Na}_4\text{Al}_3\text{Si}_3\text{O}_{12}\text{Cl}$

Quartz SiO_2

Cancrinite $(\text{Na,Ca,K})_8(\text{Al,Si})_{12}\text{O}_{24}(\text{SO}_4,\text{CO}_3) \cdot 3\text{H}_2\text{O}$

Other minerals in alphabetical order

Anatase TiO_2

Ferrihydrite $\text{Fe}_5\text{O}_7(\text{OH}) \cdot 4\text{H}_2\text{O}$

Aragonite CaCO_3

Gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Brucite $\text{Mg}_3(\text{OH})_6$

Hydrocalumite $\text{Ca}_2\text{Al}(\text{OH})_7 \cdot 3\text{H}_2\text{O}$

Diaspore $\beta\text{-Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$

Hydrotalcite $\text{Mg}_6\text{Al}_2\text{CO}_3(\text{OH})_{16} \cdot 4\text{H}_2\text{O}$

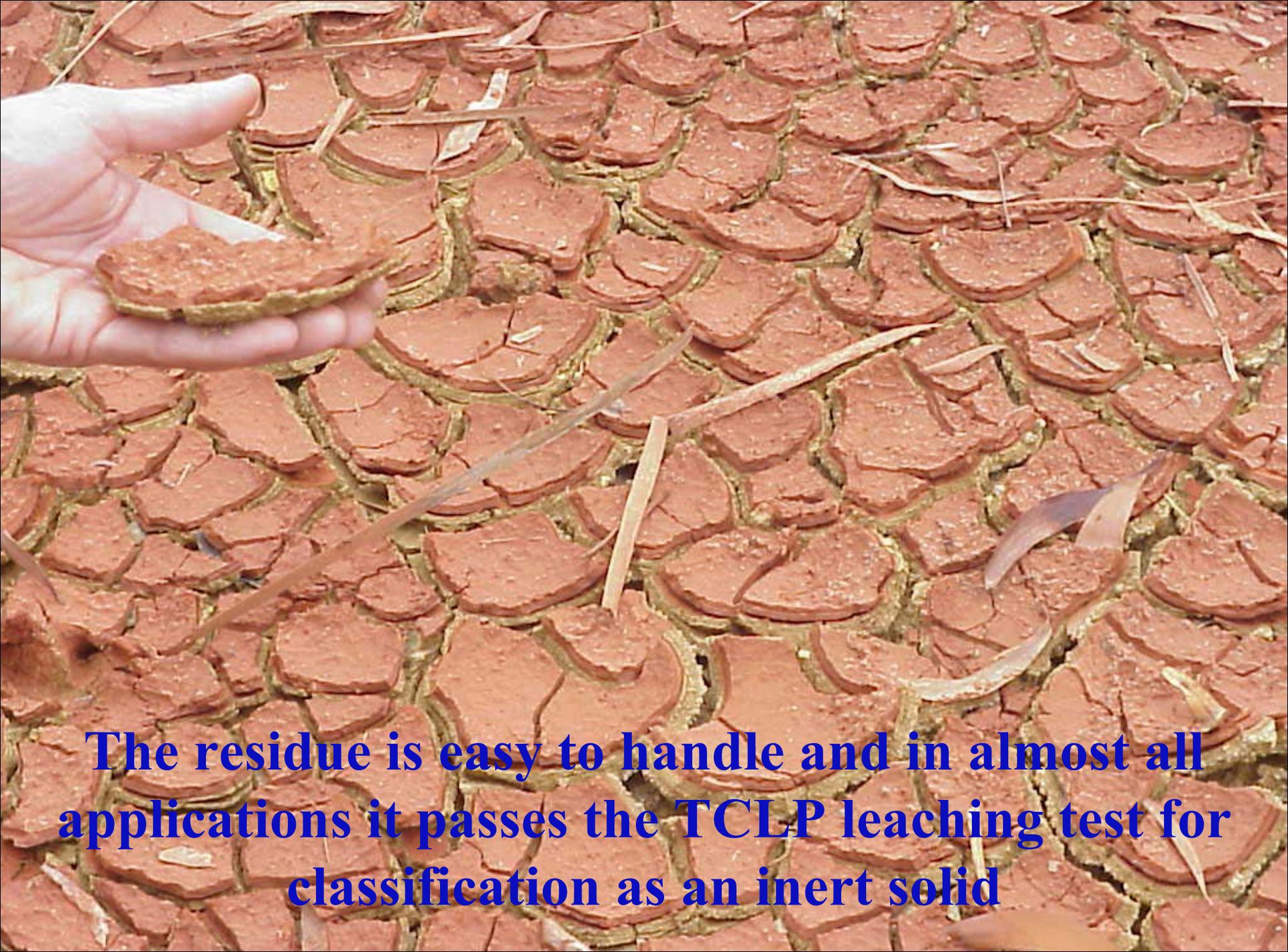
P-aluminohydrocalcite $\text{CaAl}_2(\text{CO}_3)_2(\text{OH})_4 \cdot 3\text{H}_2\text{O}$

ARSENIC REMOVAL

**When ordinary Bauxsol™ is applied by direct addition,
or used in PRBs, to treat ponded
(e.g. pit lakes, tailings dams and some industrial wastes)
or flowing
acidic water bodies,
arsenic removal is excellent**

THREE STAGE TREATMENT OF PHOSPHATE HILL WASTEWATER

Analyte	Untreated	Treated	Analyte	Untreated	Treated
pH	1.60	8.35	As ($\mu\text{g/L}$)	2,110	2
TDS (mg/L)	44,132	-	Ba ($\mu\text{g/L}$)	1,217	≤ 1
Tot-P (mg/L)	20,854	≤ 0.5	Be ($\mu\text{g/L}$)	174	≤ 1
Phos-P (mg/L)	19,667	≤ 0.5	Cd ($\mu\text{g/L}$)	465	≤ 1
K (mg/L)	230.2	28	Cr ($\mu\text{g/L}$)	9,274	≤ 1
Ca (mg/L)	934	35	Cu ($\mu\text{g/L}$)	7,041	4
Mg (mg/L)	181	1,240	Fe ($\mu\text{g/L}$)	1,253,000	16
F (mg/L)	16,100	4.0	Mn ($\mu\text{g/L}$)	324,000	51
Al (mg/L)	2,168	0.032	Ni ($\mu\text{g/L}$)	5,103	21
			Pb ($\mu\text{g/L}$)	233	≤ 1
			Th ($\mu\text{g/L}$)	75	≤ 1
			U ($\mu\text{g/L}$)	1,257	≤ 1
			V ($\mu\text{g/L}$)	2,011	36
			Zn ($\mu\text{g/L}$)	26,303	21



The residue is easy to handle and in almost all applications it passes the TCLP leaching test for classification as an inert solid

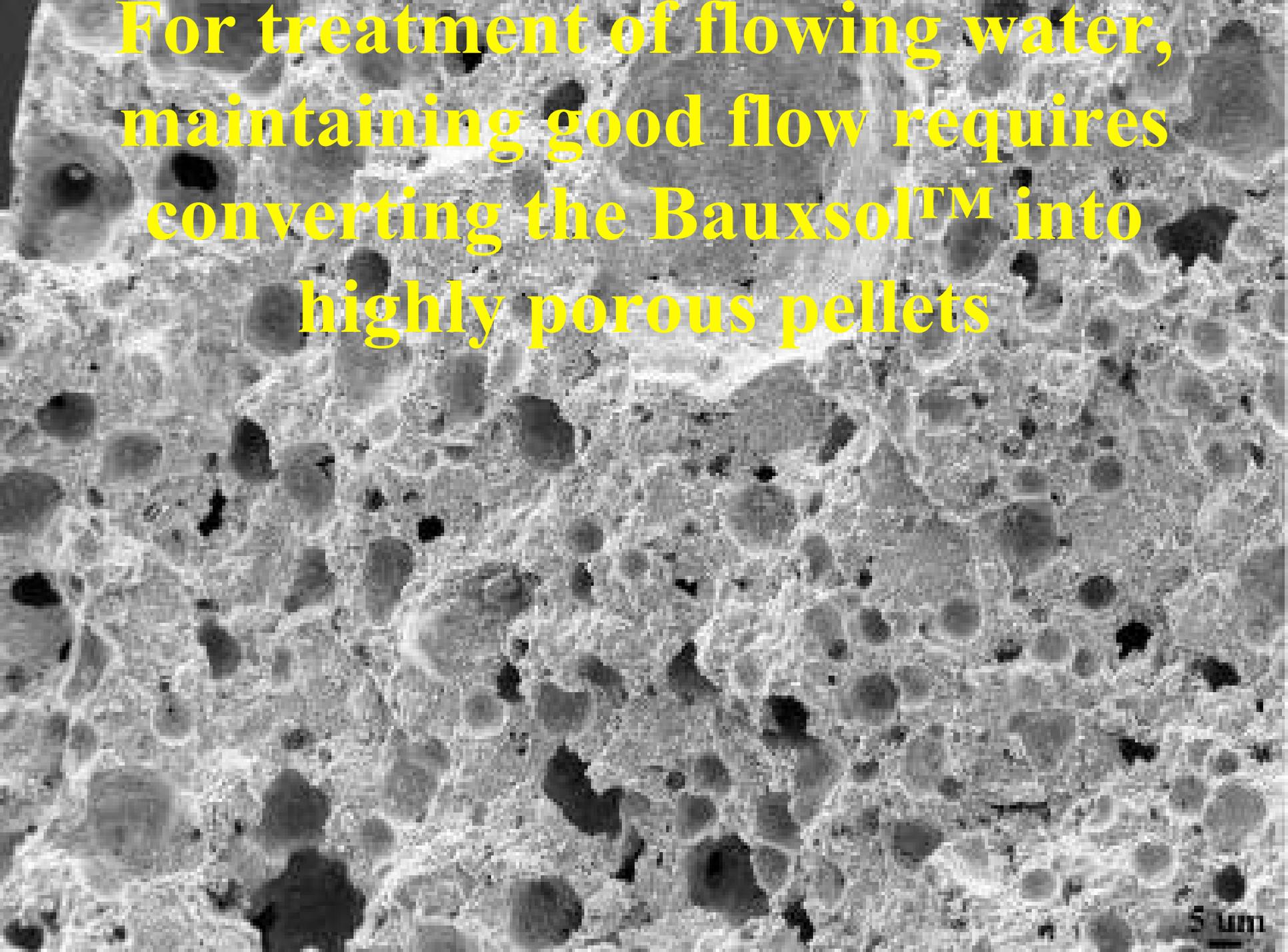


Plants grown on Bauxsol™ residues remaining after contaminated water treatment are healthy and comply with all trace element standards for human consumption

U.S. EPA leachate data for the Gilt Edge Mine, South Dakota, U.S.A.

Analyte	Control	Result 2001	Result 2002	Result 2003
pH	1.93	7.9	7.96	8.35
TDS (mg/L)	77,000	11,500	8,300	3,000
Sodium (mg/L)	9,300	2,970	2,990	570
Sulphate (mg/L)	55,000	6,000	5,800	2,200
Ag (µg/L)	150	<LLD (1)	1.1	<LLD (5)
Al (µg/L)	1,200,000	<LLD (50)	10	66
As (µg/L)	35,000	3.1	3.7	<LLD (5)
Be (µg/L)	39	0.4	0.12	<LLD (1)
Cd (µg/L)	630	<LLD (1)	0.4	<LLD (1)
Co (µg/L)	2,200	1.5	11	<LLD (10)
Cr (µg/L)	390	<LLD (1)	12	<LLD (10)
Cu (µg/L)	33,000	8.2	7.2	<LLD (10)
Fe (µg/L)	21,000,000	<LLD (25)	18	120
Mn (µg/L)	34,000	17	0.3	<LLD (10)
Ni (µg/L)	1,600	2.1	1.4	<LLD (10)
Pb (µg/L)	390	2.5	2.9	<LLD (10)
Sb (µg/L)	500	3.7	48	<LLD (10)
V (µg/L)	1,700	<LLD (1)	1	<LLD (10)
Zn (µg/L)	29,000	42	21	<LLD (10)

**For treatment of flowing water,
maintaining good flow requires
converting the Bauxsol™ into
highly porous pellets**



5 μm

**Good interconnection between
the pores is also required**

10 μm —



Simple above ground flow-through system

ARSENIC REMOVAL

**However, simple Bauxsol™ technology
can not be used effectively
to remove arsenic from ponded or flowing water
with a pH above about 7.0**

ARSENIC REMOVAL SOLUTIONS (1)

For ponded water, a good solution is to use additives, such as ferrous sulphate, ferric chloride, aluminium sulphate or jarosite minerals to create more positive charges on the surfaces of mineral particles in the Bauxsol™

Discharges from a coal fired power station Ash Pond average 20 ML/day and require treatment to remove arsenic

Effect of treatment with a Bauxsol™-FeSO₄ blend

As concentrations lowered from 170 µg/L to < 1 µg/L

Ni concentrations lowered from 21 µg/L to 12 µg/L

Se concentrations lowered from 76 µg/L to 10 µg/L

Zn concentrations lowered from 71 µg/L to 12 µg/L

The concentrations of Al, Cd, Cr, Cu, Hg & Pb were also lowered slightly but because they were near the analytical detection limits to begin with, little significance can be attached to the results

ARSENIC REMOVAL SOLUTIONS (1)

However, the Bauxsol™ blends can not be used to treat flowing water with a near neutral or slightly alkaline pH because the OPC (ordinary Portland cement) used to make the pellets raises the pH too much and the use of coarse sand fillers results in low hydraulic conductivity and adds too much weight and inert volume

ARSENIC REMOVAL SOLUTIONS (2)

Another solution is to use Bauxsol™ that has been acid washed to remove minerals that provide the solid alkalinity, thereby increasing the proportion of positive surface charges on particles

This method is very effective and provides arsenic removal capacities of about 3.5 g As /kg of acid washed Bauxsol™ with contact times of < 30 mins

However, it can not be used with pelletized Bauxsol™ because the acid wash destroys the OPC binder

ARSENIC REMOVAL SOLUTIONS (3)

There are two possible solutions to this problem

One is to develop a porous pellet that has a reaction pH of less than 7.0 and does not use OPC.

We are currently developing a ceramic pellet that uses feldspathoid mineral precipitates as binders, but work is still in progress

The other is to coat a light material with acid washed Bauxsol™. We have chosen activated charcoal for this purpose, but materials such as zeolites or diatomite would also be viable options

ARSENIC REMOVAL SOLUTIONS (4)

Laboratory tests indicate that this acid washed Bauxsol™ can bind about 5 g of As / kg of Bauxsol™ and that the bound arsenic is very difficult to remove from the spent Bauxsol™ unless the pH of the leaching solution is above 10.5

ADDITIONAL NOTES ON ARSENIC REMOVAL (1)

1. Bauxsol™ does remove arsenite, but the efficiency is only about 10% of that for the removal of arsenate.
2. Once the As is bound to Bauxsol™ it can not be removed to any significant extent unless the pH of the leaching solution is raised above 10.5. Therefore, spent Bauxsol™ may not need to be disposed of in a toxic waste facility. We don't yet know exactly how As is bound, but because it can not be readily desorbed, we suggest that it is not finally bound by simple adsorption mechanisms.
3. Bauxsol™ can lower As concentrations to $< 0.5 \mu\text{g/L}$.

ADDITIONAL NOTES ON ARSENIC REMOVAL (2)

- 4. Full activation of the Bauxsol™ (including calcination) can improve its performance when compared to acid washed Bauxsol™, but the improvement is not sufficient to justify the cost.**
- 5. For effective treatment, the As should be present as arsenate and if arsenite is present, it should be oxidized before treatment with Bauxsol™.**
- 6. Bauxsol™ will also lower the concentrations of other metals that may be present in the water; its ability to remove arsenate is not adversely affected by the presence of other metals.**

ADDITIONAL NOTES ON ARSENIC REMOVAL (3)

7. Arsenic uptake by Bauxsol™ is interfered with by anions such as phosphate and sulphate, but the interference is not serious. Arsenate can be removed in the presence of sulphate at seawater concentrations. (Bauxsol™ can also remove up to 50 g of phosphate per kg of Bauxsol™).
8. Radium is often present in water requiring treatment and Bauxsol™ can lower Ra concentrations to < 0.5 pCi/L. However, the Bauxsol™ required to remove Ra is not as effective when acid washed. Therefore, where both As and Ra need to be removed, a two stage treatment will be required.