National Slag Association

Founded in 1918

National Slag Association
. . . In the Beginning!

- **Established in 1918 to address the huge volumes of slag being generated by the iron and steel industry. At that time . . . .**
  - **40,000,000 tons of pig iron being produced.**
  - **20,000,000 tons of slag being generated.**
- **Association adopted the mission to fully identify new potential applications for this co-product of the iron and steel industry.**

National Slag Association
. . . Today!

"SLAG . . . The Material of choice"

- In excess of 20,000,000 tons of slag produced and marketed annually.
- Member companies work closely together to expand utilization and develop new applications.
- Over the past 90 years slag has earned a reputation for long term performance across a wide range of responsible, environmentally sound applications.
- Through a commitment to safe and productive plant operations, NSA member companies continue to demonstrate their dedication to "Safety First"!

SLAG . . . A Green Product in its Own Right !

SLAG . . . An Industrial Co-Product of the Iron & Steel Industry

SLAG

"A material which tends to be mischaracterized and misunderstood!"

SLAG: A Proud History of Use for this Co-Product !

- **Slag usage in road building dates back 2000 years ago to Roman road building.**

"Appian Way" in Italy

SLAG: A Proud History of Use for this Co-Product !

- As early as 1589, Germany made cannon balls out of iron slag.

SLAG: A Proud History of Use for this Co-Product !

- Perhaps the first introduction of iron slag to America came with the pilgrims as slag was used as ship ballast.

SLAG: A Proud History of Use for this Co-Product !

- **Cast iron slag stones were used for masonry work in Europe in the 18th century.**

SLAG: A Proud History of Use for this Co-Product !

- Slag roads in England go back to 1813.

SLAG: A Proud History of Use for this Co-Product !

- First Slag road built in the US in 1830.

- By 1880 cast blocks of slag were in general use for street paving in both Europe and America.

SLAG: A Proud History of Use for this Co-Product !

- **Major early use in America was as ballast for railroads.**

SLAG

WHAT IS SLAG . . . . ???

SLAG

- **AS OLD AS THE SMELTING PROCESS ITSELF!**
- **Every metallurgical smelting process generates Slag as a co-product.**
- **Slags used in construction applications are primarily co-products of the Iron and Steel making industry.**

Types of Slag

- **Iron Blast Furnace Slag (BFS)**
  - Air Cooled
  - Granulated
  - Pelletized
- **Steel Furnace Slag (SFS)**
  - Basic Oxygen Furnace (BOF)
  - Electric Arc Furnace (EAF)
- **Other Slags**
  - Foundry
  - Cupola
  - Ladle Metallurgical Furnace

Steel-Making Process

Integrated Mills:

- Blast Furnace Slag (BFS)
- Basic Oxygen Furnace Steel Slag (BOF)

Mini Mills:

- Electric Arc Furnace Steel Slag (EAF)

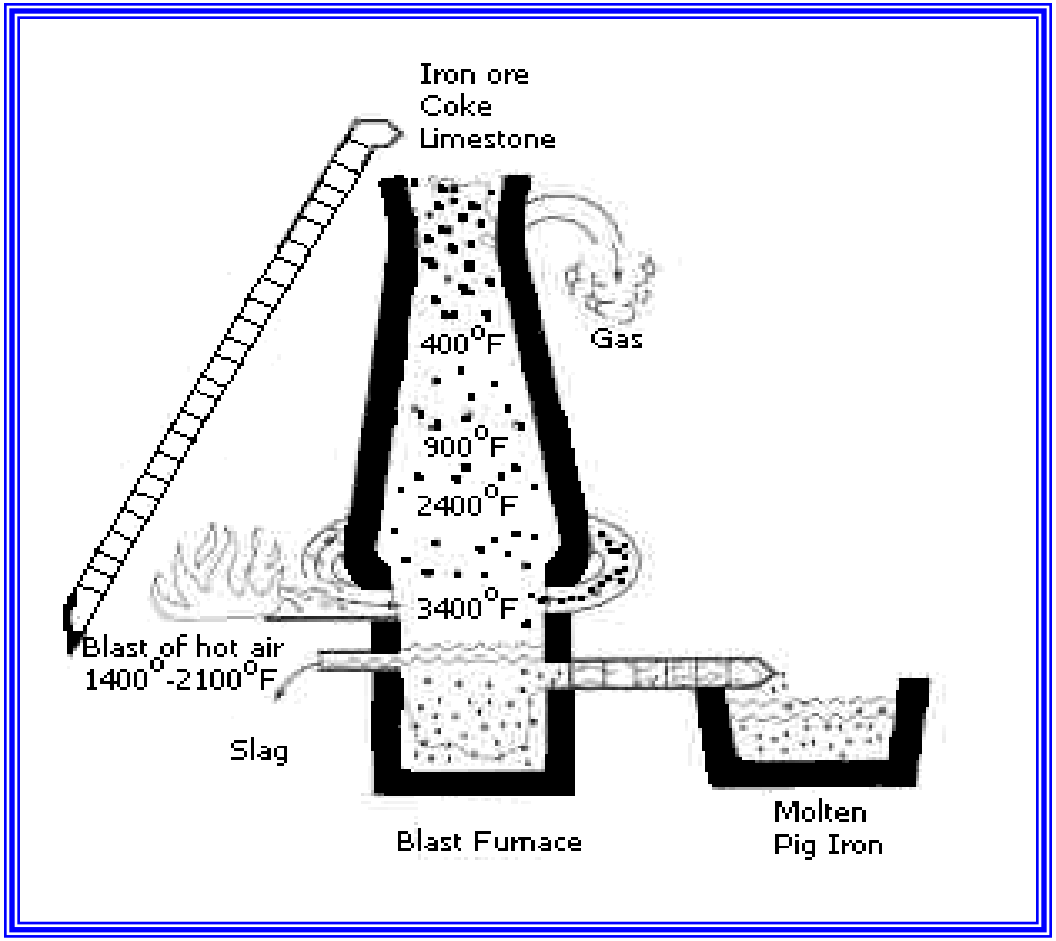
Integrated Mills

Blast Furnace Slag (BFS)

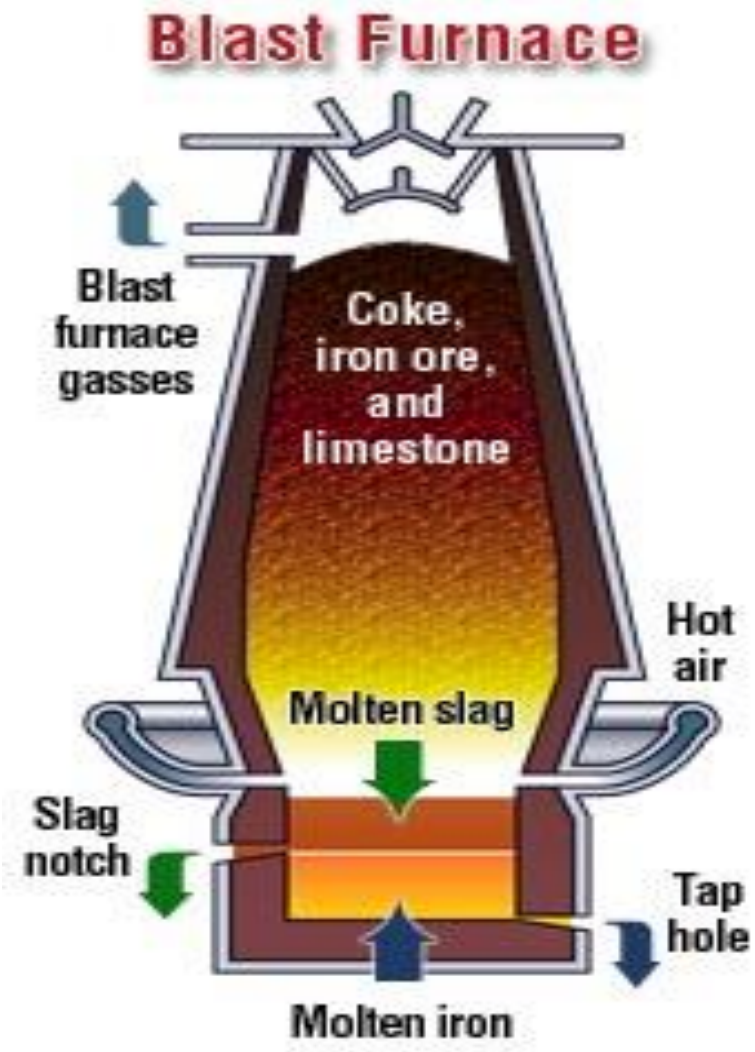
BLAST FURNACE SLAG

Blast Furnace Slag is formed when iron ore or iron pellets, coke and a flux (either limestone or dolomite) are melted together in a blast furnace. When the metallurgical smelting process is complete, the lime in the flux has been chemically combined with the aluminates and silicates of the ore and coke ash to form a non-metallic product called blast furnace slag. During the period of cooling and hardening from its molten state, BF slag can be cooled in several ways to form any of several types of BF slag products.

Iron Slag Making Process Through a Blast Furnace



Iron Blast Furnace



Blast Furnace Slag (BFS)

- **Blast Furnace Slag is most often processed by allowing it to slowly cool by ambient air (Air Cool Blast Furnace Slag or ABCF), is processed through a screening and crushing plant, and then processed into different sizes for use primarily as an aggregate.**

- **In some instances Blast Furnace Slag may undergo either an expansive or pelletizing process for use in different applications.**

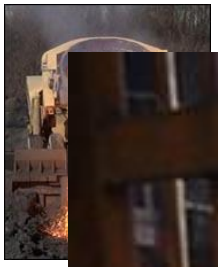
GRANULATED SLAG

Granulated Blast Furnace Slag

(GBFS)

GRANULATED BLAST FURNACE SLAG

Granulated Blast Furnace slag is produced by being rapidly cooled by large quantities of water to produce a sand-like granule with glass-like properties.




Granulated
Blast Furnace Slag

GRANULATED BLAST FURNACE SLAG

➢ Granulated Blast Furnace Slag Applications:

- Ground to produce Slag Cement.
- Construction Aggregate (lightweight fill)
- Raw material in the manufacture of Portland Cement
- Raw material in the manufacture of glass

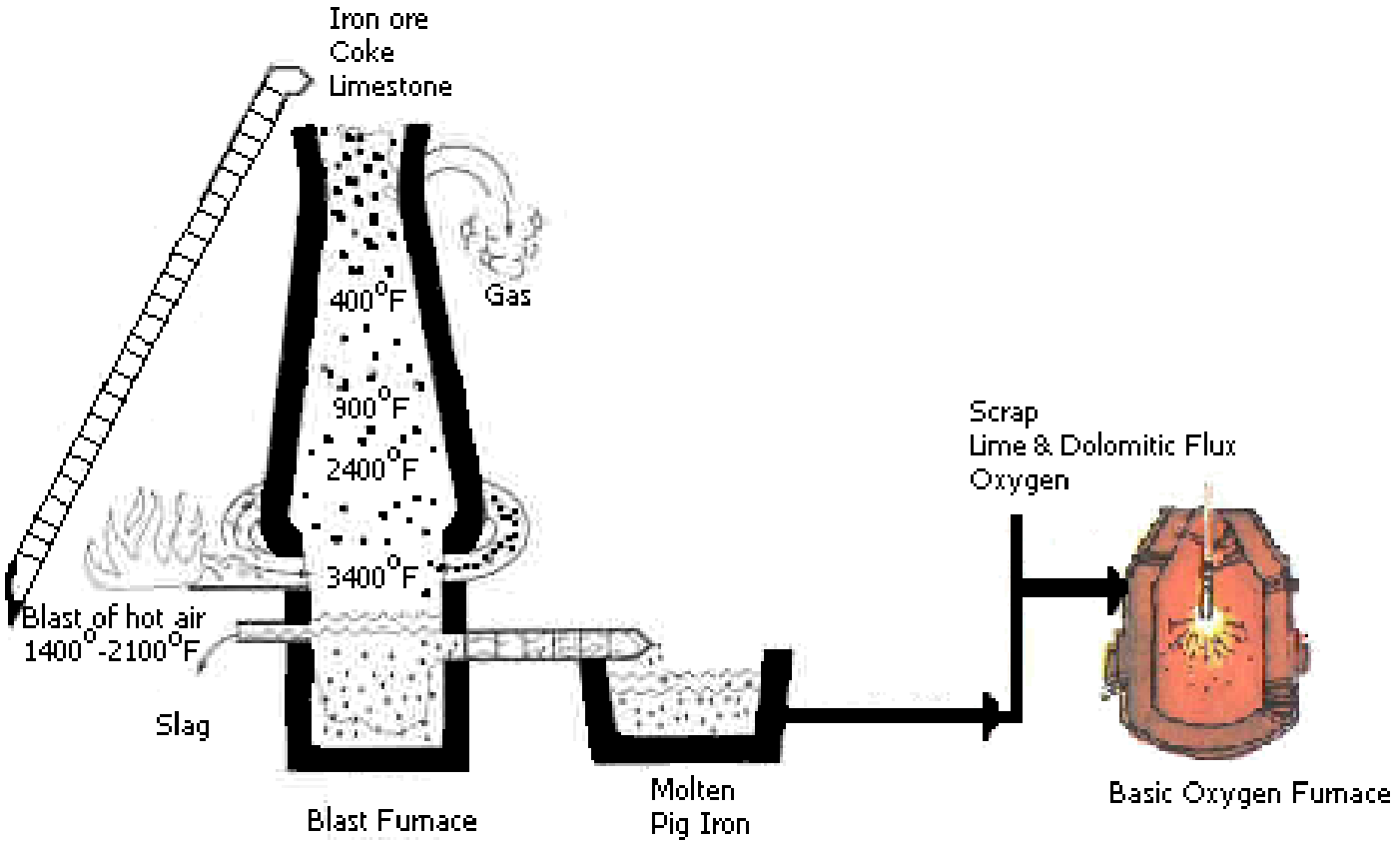
Steel Slag

- Basic Oxygen Furnace Slag (BOF)
- Electric Arc Furnace Slag (EAF)

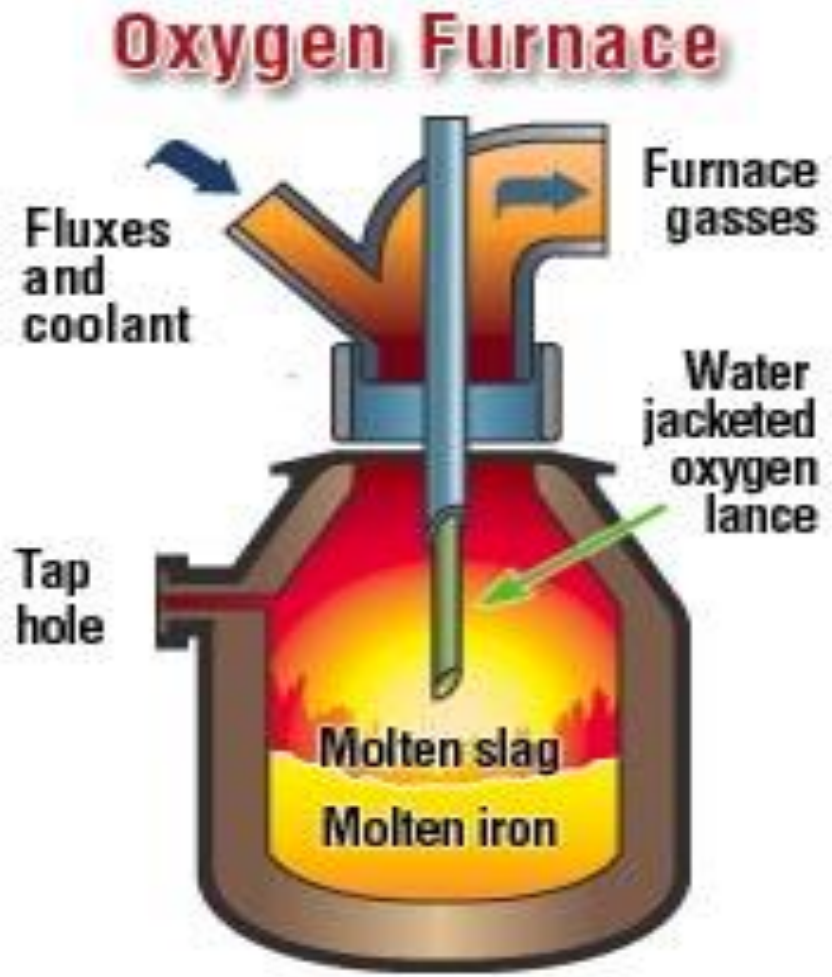
STEEL FURNACE SLAG

Steel Furnace Slag is produced in a (BOF) Basic Oxygen Furnace or an (EAF) Electric Arc Furnace. Hot iron (BOF) and/or scrap metal (EAF) are the primary metals to make steel in each process. Lime is injected to act a fluxing agent. The lime combines with the silicates, aluminum oxides, magnesium oxides, manganese oxides and ferrites to form steel furnace slag, commonly called steel slag. Slag is poured from the furnace in a molten state. After cooling from its molten state, steel slag is processed to remove all free metalilcs and sized into products.

Steel Slag Made Through A Basic Oxygen Furnace



Basic Oxygen Furnace

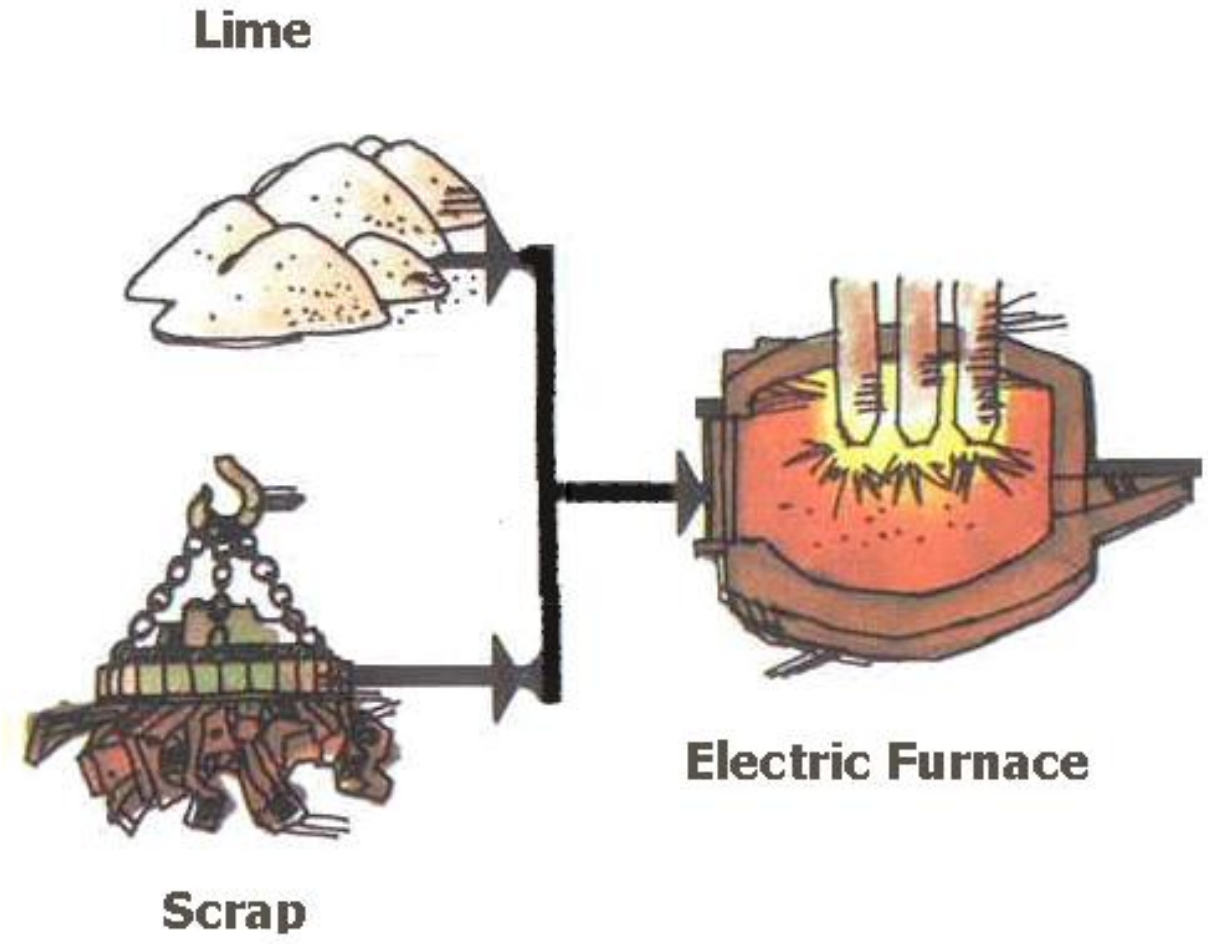


Mini Mills

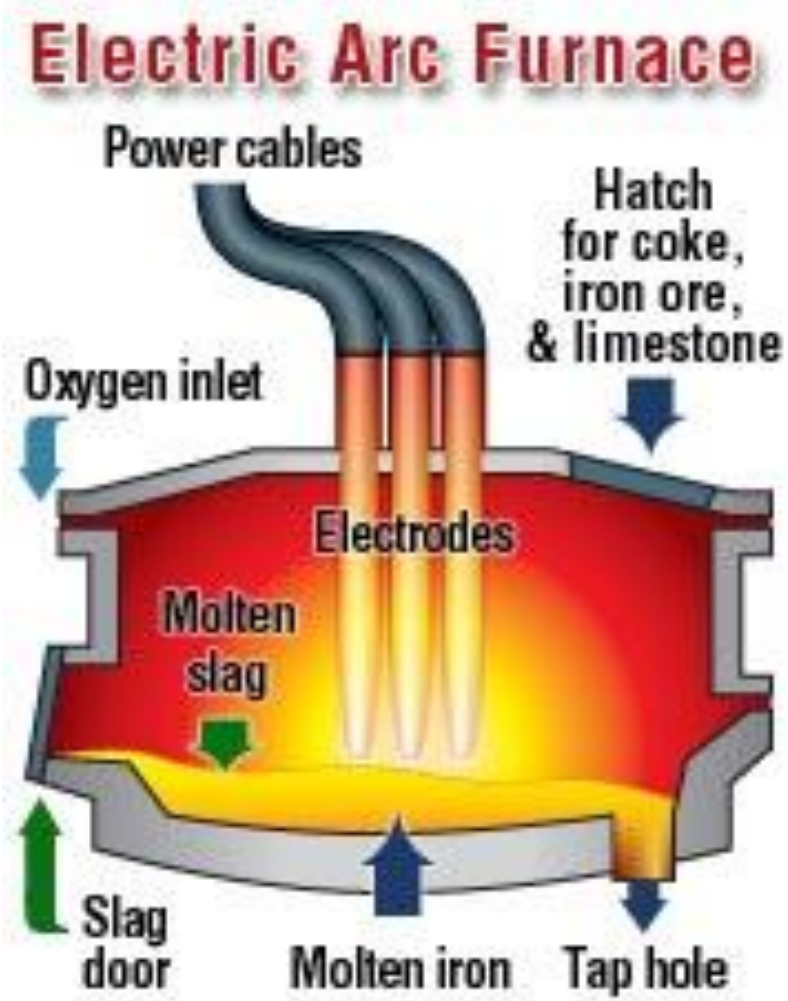
Steel Slag

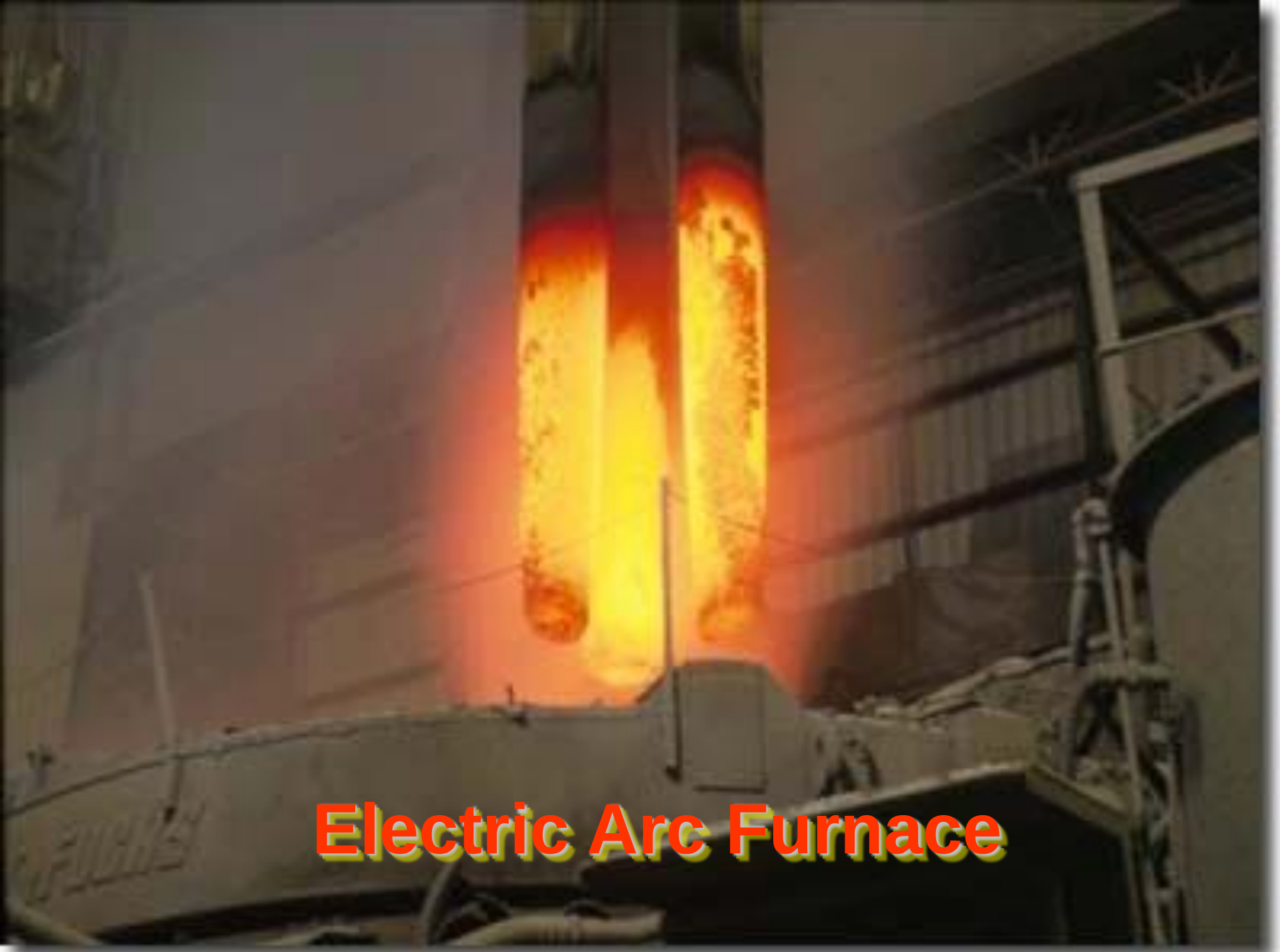
Electric Arc Furnace Slag (EAF)

Process of Steel Slag (EAF)



Steel Slag (EAF)




Electric Arc Furnace

STEEL FURNACE SLAG

Steel slag is processed as an air-cooled material. The free metallics are magnetically separated and the material is separated and sized into construction aggregates, used as an agricultural soil amendment, as a raw ingredient in Portland cement production, as an environmental remediation material and other uses.

Foundry Slag / Cupola Slag

- **Slags produced by metal casting foundries subject to the type of process being used.**
  - **Cupola Slag (air-cooled or water-quenched)**
  - **Induction Furnace Slag**
  - **Electric Arc Furnace Slag**
  - **Desulphurization Slag**

- **Properties and chemistries vary widely due to the type of processing and materials used.**

Ladle Metallurgical Furnace Slag

- Slags that are co-products of specialized iron or steel manufacturing.
- Ferroalloys and Fluxes are added to the ladle to drive attainment of a particular chemistry.
- Slags possessing specialized chemistries such as high CaO can be produced.
- Volumes of Slag produced are generally lower than that typically seen in an iron or steel blast furnace.

Other Proven Uses for Slag !

Clinker From Steel Making Slags

"A Productivity and Environmental Solution"

Steel Industry

Cement Industry

Why is Slag of interest to the Cement Producer . . . ?

The Chemistry of Slag is very similar to the basic materials found in Portland Cement !

SLAG & CEMENT PRODUCTION

- **Slag has been proven to be a valuable material addition in the Cement Production Process**
  - **Can be used as a supplemental raw material addition to the materials blended as feed and fed into a kiln to produce cement clinker.**
  - **Can be used as a grinding aid in the cement grinding and finishing process.**

SLAG & CEMENT PRODUCTION

➢CemStar

- ***Patented Process that uses Steel Slag and/or ACBF Slag added directly into the back of a cement kiln during the pyro-processing (burning) process to create cement clinker.***

CemStar

- Increases the Production of Cement Clinker. *(Slag is precalcined !)*
- Reduces the consumption of natural fuels while increasing Productivity.
- Reduces Greenhouse Gases
  - CO_2
  - NOx
  - Sox
- Increases the Sustainability of Natural Aggregate Sources.

Steel Furnace Slag

Construction Aggregate Applications

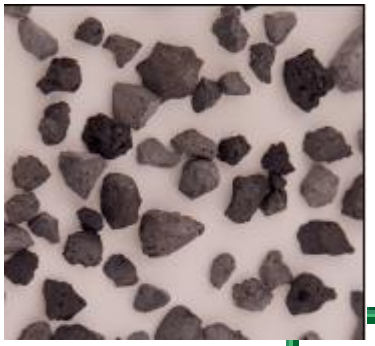
Steel Furnace Slag

- **Aggregate Properties:**
  - **Rough, cubicle texture**
  - **Increased toughness & soundness**
  - **No deleterious materials**

Rounded Uncrushed Gravel

Flat & Elongated Limestone

Cubical Steel Slag



Steel Furnace Slag for Bituminous Paving

- **Steel Slag has evolved as an ideal aggregate in Hot Mix Asphalt (HMA) surface mixture applications.**
  - **Superior Skid Resistance**
    - **Improved frictional properties**
    - **Higher coefficient of friction than most natural aggregates.**
  - **High Shear Strength**
    - **Resistance to rutting**

Steel Furnace Slag

"Chip and Seal"

Steel Furnace Slag

Chip and Seal

1. After the surface has been prepared by patching, crack filling, etc. a binder is sprayed from a computer controlled and calibrated spray unit.

2. Then a layer of aggregate is applied using a computer controlled and calibrated self-propelled chip spreader.

3. The process is completed by compacting the surface via several passes from a multi-tired roller.

Steel Furnace Slag

Chip and Seal

- **Physically, many natural aggregates are unable to provide a surface that will resist polishing, therefore, they easily become slippery when wet.**
- **Steel slag contributes a high coefficient of friction to the roads surface by providing the roughness necessary to attain a skid resistant pavement.**
- **Steel Slag, with its hard, angular, skid resistant shape, low absorption, and greater asphalt binder affinity is the most advantageous choice of aggregate for Chip and Seal applications.**

Steel Furnace Slag

"Chip and Seal"

Chip and Seal is a cost-effective method of resurfacing low-volume roadways in rural areas!

ACBF & Steel Furnace Slag

Other Construction Applications

- Unimproved Roadways & Parking Lots
- Driveways
- Shoulders & Berms
- Embankments
- Fill Applications

Steel Furnace Slag

➢ Base & Fill Applications

- The chemical composition of some Steel Slag tends to be expansive and should not be used where potential expansion would be detrimental. This is especially true where a dense graded aggregate is used as a base or fill.

- Depending upon the level of potential expansion and material gradation, confined applications such as bases under pavements and structures may need to be avoided.

- Most Steel Slags however are suitable for use in applications where expansion will not be an issue such as in an open-graded fill or road surface course.

Pipe Bedding for Sewer and Storm Water Pipe

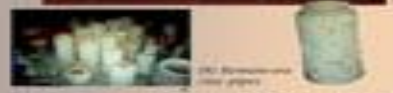
Sewer Pipes Through the Ages

Ancient Pipes

Mohenjo-Daro, a town of 35,000 in the Indus River Valley (southern Pakistan), is considered by many historians to be the birthplace of sewers. Beginning around 3500 BCE, drains made of cut stone or man-made masonry units, initially open-topped but later covered, were developed and became the prototype of many surface drains used throughout the ancient world—the forerunners of pipe.

The birth of pipe occurred at about the same time in Babylon (Iraq)—sun-cured (and later baked) terra cotta pipe made on wooden mandrels, with bell and spigot joints.

The idea of sewers and pipes spread far and wide over the next few thousand years—into Asia, the Middle East and Europe. The Roman Empire particularly had an extensive system of cut stone sewers and developed the use of circular lead pipes for water. Their revenue of lead is thought to have contributed to their shortened life expectancies.



Early Pipes in Europe

The Dark and Middle Ages saw a drastic decline in sanitation. Though cast iron pipe was used as early as the 1600s in France, generally pipes were crudely made in this period.

After several plagues swept across Europe, Paris was one of the first cities to set about creating a comprehensive sewer system. From the 1800s to the 1890s, the Parisians built a sewer under almost every street—nearly 400 km in all. These sewers incorporated many new ideas: low flow channels; sidewalks for sewer men; unique devices to clean the sewers, including boats; and the placement of other utility mains inside sewers.

Horrific sanitation conditions in London led to construction of a new sewer system in the 1860s. Egg-shaped sewers and "separate" sewers (no storm water) were developed in England. The new concepts spread rapidly throughout Europe. Typically, large sewers were built of brick or cut stone, the smaller ones of clay, cast iron or wood.

U.S. Experience

In the United States, cholera and other diseases became a problem after the Civil War, and the first generation of American civil engineers looked to England and Europe for solutions. The first new separate sanitary sewer system was in Memphis, Tennessee, initially using 6" ID clay pipe (no manholes), and later 8" ID (with manholes). Clay became the dominant pipe material for a time across the U.S., and clay pipe factories rose throughout the United States.

The availability of wood and the re-training of carpenters/furniture makers, etc., facilitated the use of wood for water and sewer pipe, though sewage and wood did not work well together because of the adverse effects of the sulfides and sulfuric acid common to sewage. The simplest wood pipes were hollowed-out logs. Others were made with wood staves, often wound with steel wire for strength.

The basic design of sewers has not changed substantially since the mid-to-late 1800s, but many pipe materials have been added to the early choices. The first U.S. cast iron foundry appeared in New Jersey in the early 1800s, and Philadelphia was the first U.S. city to use cast iron exclusively for a time. Steel was sometimes used but was less common due to its cost. Clay brick (salt-glazed and later vitrified) was widely used and is still in beneficial service in sewers throughout the US.

The scarcity of materials during and after World War II led to some unusual pipe materials, including British papier mache pipe made from old newspapers impregnated with pitch. Coal-tar-impregnated wood fibre pipe (often called Orangeburg or Black pipe) evolved to help reduce the cost of housing after World War II. Ground-up wood cellulose fibre was centrifugally spun to form the wall of a circular pipe. Once dried, the pipe was dipped in hot coal tar to fill any voids in the pipe wall. This was the pipe material of choice for laterals from the mid-1940s to the early- to mid-1970s, when plastic pipe drove this material out of business.

Today, the sewer pipe materials available include vitrified clay, polyvinyl chloride, HDPE, ductile iron and reinforced concrete pipe. Installation techniques are steadily changing from the open-trench approach to trenchless methods. Although PVC was first recognized as a material in 1835, it was first tried for water and sewer pipe in Germany in the 1930s. Ductile iron was first developed during WW II and used as a pipe material starting in the 1960s.

Steel Furnace Slag

- **Pipe Backfill**
- **Leach Field Stone**
- **Septic Stone**

Cloacina - Goddess of the Sewers

There are no known images of Cloacina except on coins. Based on her association with Venus, she probably looked much like other representations of Venus (Shown here: Capitoline Venus [1]). Cloacina's name is either derived from the Latin *cluere* (to wash, purify, or clean) or from the Latin *cloaca* (sewer).

The Shrine of Cloacina

The model to the right shows the Basilica Aemilia (☛) in the Roman Forum with the circular shrine of Venus Cloacina in front. The shrine stood at the place where the Cloaca Maxima entered the Forum (see map below) and may have included a manhole entrance into the sewer. Its placement in the forum indicates an important status for Cloacina.

2

3

Ruin of the shrine showing its circular base

Drawing of the Shrine of Cloacina (Cloacinae Sacrum). Both figures may be Cloacina, or one may be Venus.

Cloacina

Rome was justly proud of its extensive sewer system and embodied this pride in a goddess - Cloacina, the patron goddess of the Cloaca Maxima and the city's sewer system and workers. She is thought to have been initially adopted from Etruscan culture. Over time, Cloacina became identified with Venus, the goddess of love. She was celebrated in a shrine in the Roman Forum (an important civic center in Rome), and was featured on Roman coins and in poems:

> *O Cloacina, Goddess of this place,*
> *Look on thy suppliants with a smiling face.*
> *Soft, yet cohesive let their offerings flow,*
> *Not rashly swift nor insolently slow.* [7]

42 BCE coin ► showing the Shrine of Cloacina

4

Modern views of the Cloaca Maxima show its hewn-stone construction; sections of this system are still in use today for utilities and drainage approximately 2500 years after its installation.

5

6

Cloaca Maxima - Rome's Greatest Sewer

The largest sewer in Rome's system was a massive drain made of cut stone, known as the Cloaca Maxima, or "Main drain," portions of which still exist and are in service today. Construction of the Cloaca Maxima began circa 500 BCE, probably by Etruscan workers. Its original purpose was to drain a marsh upon which a large portion of the city was eventually built. The Cloaca Maxima discharged its flow into the Tiber River. (The Cloaca Maxima soon became a "combined" system, since most waste from the city was thrown into the streets, waiting for either the city's extensive street-flushing program or rain to flush it into the underground sewer system.) Early on, drains from public buildings and the homes of important public officials were the only "private" connections allowed to drain directly into the system and the Cloaca Maxima. Laterals from other buildings and the vast majority of the city's homes were illegal until approx. 150 AD.

8

9

Cutaway view of a typical Rome street, showing lead water pipes and the sewage drain – all under the surfaced street. Laterals brought sewage into the system from nearby buildings/homes. The overall system had many smaller "collector" and "trunk" sewers, most of which eventually drained into the Cloaca Maxima and on into the Tiber River.

10

11

◄ The Cloaca Maxima became famous and appeared in artwork for many centuries, including these views of its outlet into the Tiber River (#10), and Saint Sebastian's body being thrown into the Tiber River (#11) near the Cloaca Maxima's outlet (seen in the background).

Credits: Poster design by Jan McDonald. Poster production by Hale Barnes. Research by Jon Schladweiler, Paul Matz, and Kevin Enlinger. Illustrations: 1. P. Sullivan; 2. André Caron, Québec, www.maquettes-historiques.net; 3. University of California at Los Angeles; 4. Professor Richard Prior, Fordham University; 5. www.sadoruma.com; 6. Jona Lendering, www.livius.org; 7. Attributed to Lord Byron (may be tongue-in-cheek); 8. Wikipedia; 9. Jan McDonald; 10. E. Roesler Franz (1845-1907), "Sbocca della Cloaca Massima," Museo di Roma; 11. Lodovico Carracci, "St Sebastian Thrown into the Cloaca Maxima" (1612), J. Paul Getty Museum.

Sponsored by the Pima County Wastewater Management Department and the Arizona Water & Pollution Control Association.

COMMON USES FOR SLAG

Blast Furnace Slag			Steel Slag
Air-Cooled	Pelletized	Granulated	
Asphalt Aggregate	Concrete Masonry Aggregate	GGBFS Cement	Asphalt Aggregate
Concrete/Masonry Aggregate	Lightweight Concrete	Soil Cement	Fill
Insulation/Mineral Wool	Insulation	Roller Compacted Concrete	Cement Mfg. Raw Feed
Cement Mfg. Raw Feed	Lightweight Fill	Agricultural/Soil Amendment	Agricultural/Soil Amendment
Agriculture/Soil Amendment	Road Base		Environmental Applications
Base & Fill Material			Railroad Ballast
Roof Aggregate			Road Base
Railroad Ballast			Gabions/Rip Rap
Glass Manufacture			
Environmental Applications			
Gabions/Rip Rap			

Agricultural Applications

- **Substitute for Agricultural Lime**
- **Valuable for Remineralization:**

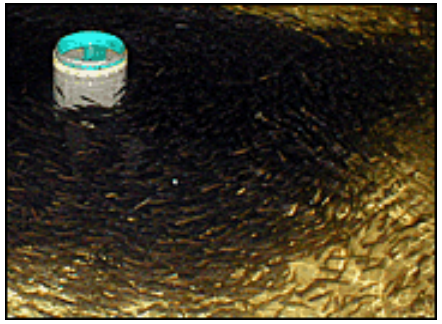
Calcium	Iron
Copper	Boron
Magnesium	Zinc
Manganese	
Sulfur	
Molybdenum	

Slag's use for Environmental Remediation

Water Purification

Water Filtration

Permeable Reactive Barrier



Phosphorus Removal

Erosion Control

Environmental Remediation

- **Water Purification**
- **Hazardous Chemicals**
- **Permeable Reactive Barriers**

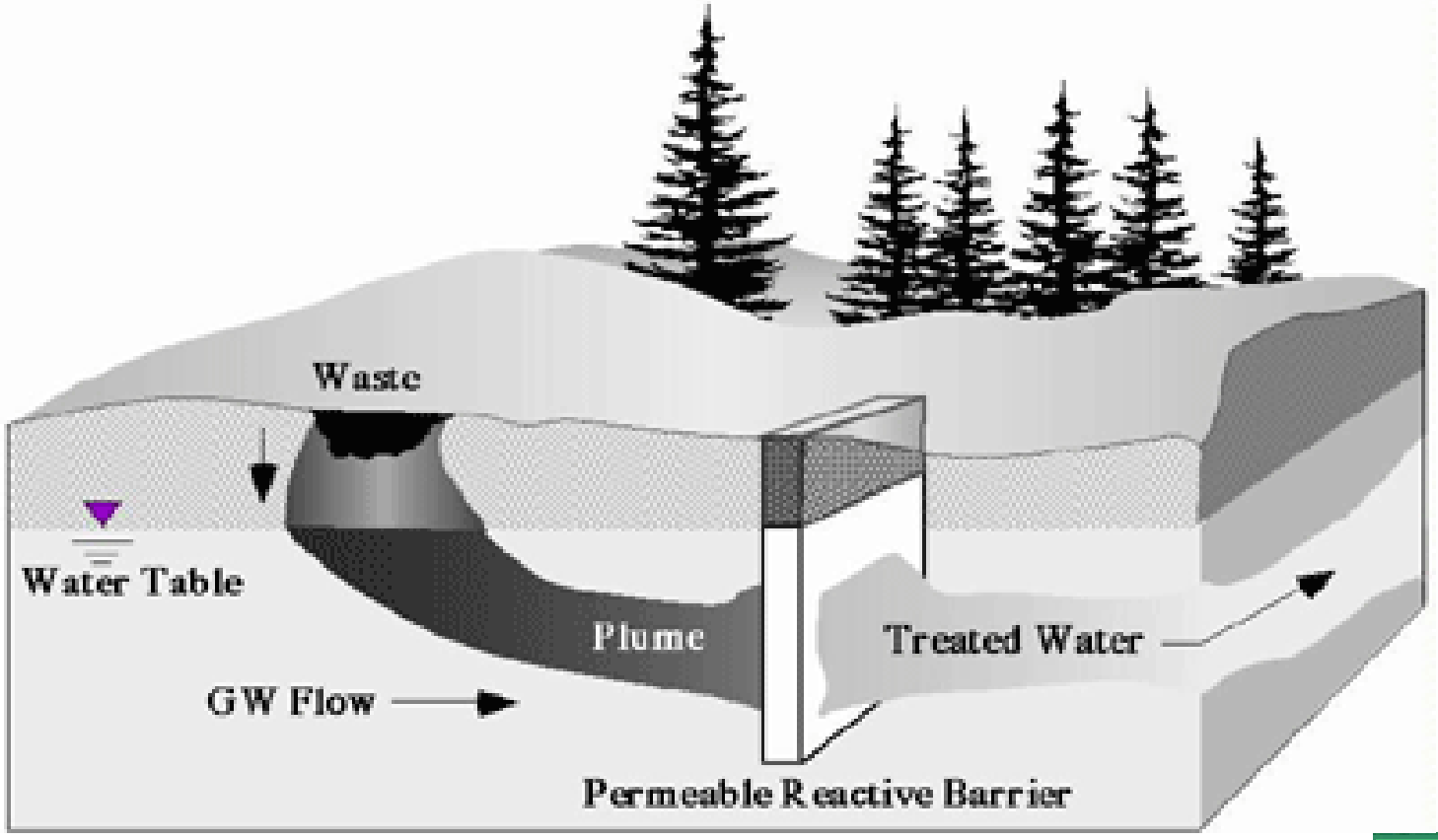
- **Acid Remediation**
  - ✓ **Acid Mine Drainage**
  - ✓ **Phosphorus**

- **Waste Pollution Remediation (Constructed Wetlands Technology)**
  - ✓ **Manure Pit Effluents**
  - ✓ **Barnyard & Feed Lot Effluents**
  - ✓ **Milk House Effluents**

Slag Utilization for Water Pollution Remediation

Slag for Permeable Reactive Barriers

Slag for Permeable Reactive Barriers



SLAG for Acid Mine Drainage

National Slag Association Annual Meeting 2006

Presentation on the utilization of Slag to reduce Acid Mine Drainage

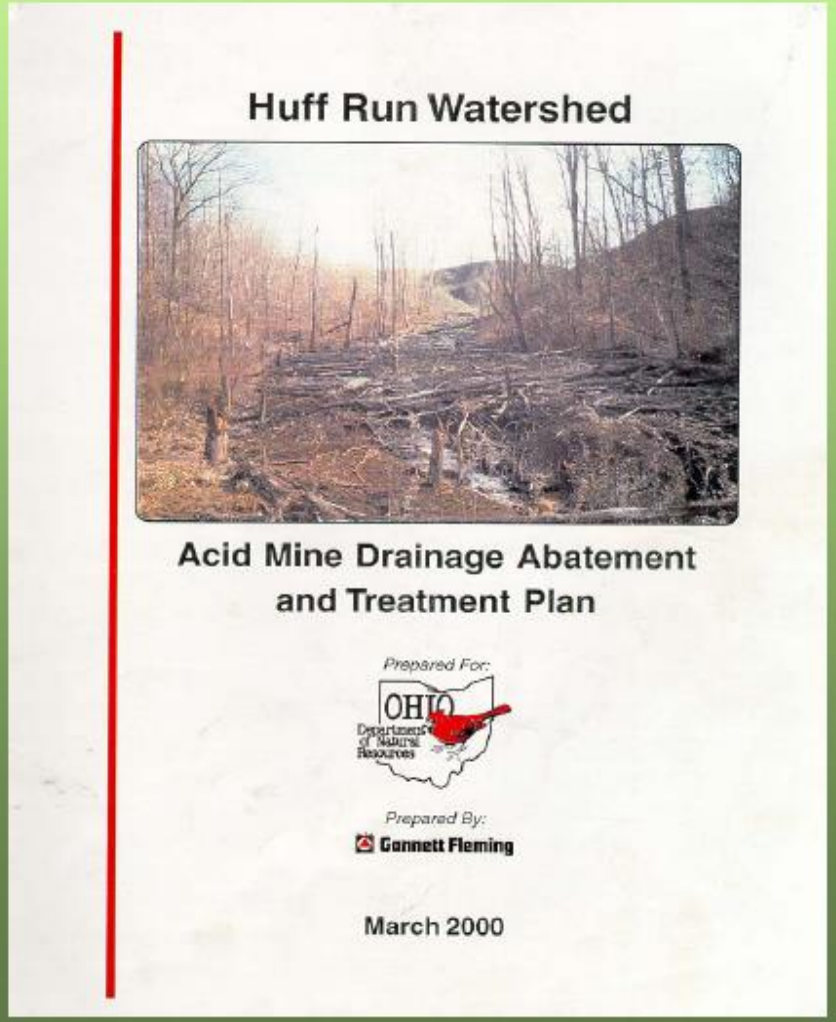
Jim Gue – Ohio Department of Natural Resources

"PASSIVE TREATMENT OF ACID MINE DRAINAGE USING STEEL SLAG IN THE HUFF RUN WATERSHED "

Huff Run Watershed

- Muskingum Conservancy District
- Tuscawaras River Basin
- Conotton Creek
- 10 miles length
- 14.1 sq miles

A Primary Huff Run AMDAT Goal:



"Identify and develop AMD abatement Projects in reaches 4 and 5 to buffer downstream episodic low flow pH excursions."

Pre-Construction Water Quality

Project Sample Location	pH	Fe	Mn	Al
Seep at Headwaters	5.8	.648	18.5	.357
Pond 1	2.99	6.94	44.1	21.3
Pond 2	6.64	.258	1.44	<.25
Impoundment 4	4.64	.169	12.3	.987
Impoundment 6	6.28	1.85	5.47	<.25
Wetland Outlet	4.78	.302	15.1	.51
Site Discharge	3.97	.75	18.8	3.33

pH (SU)

Metals (mg/l)

Steel Slag Advantages:

- Steel slags yield several hundred times more alkalinity per equal weight than limestone
- High alkalinity with low contact time
- Low cost ($12.00/ton at Lindentree Project)
- Ease of availability
- Long-term passive treatment

Limestone/Steel Slag Channel

Limestone/Slag Treatment Swale

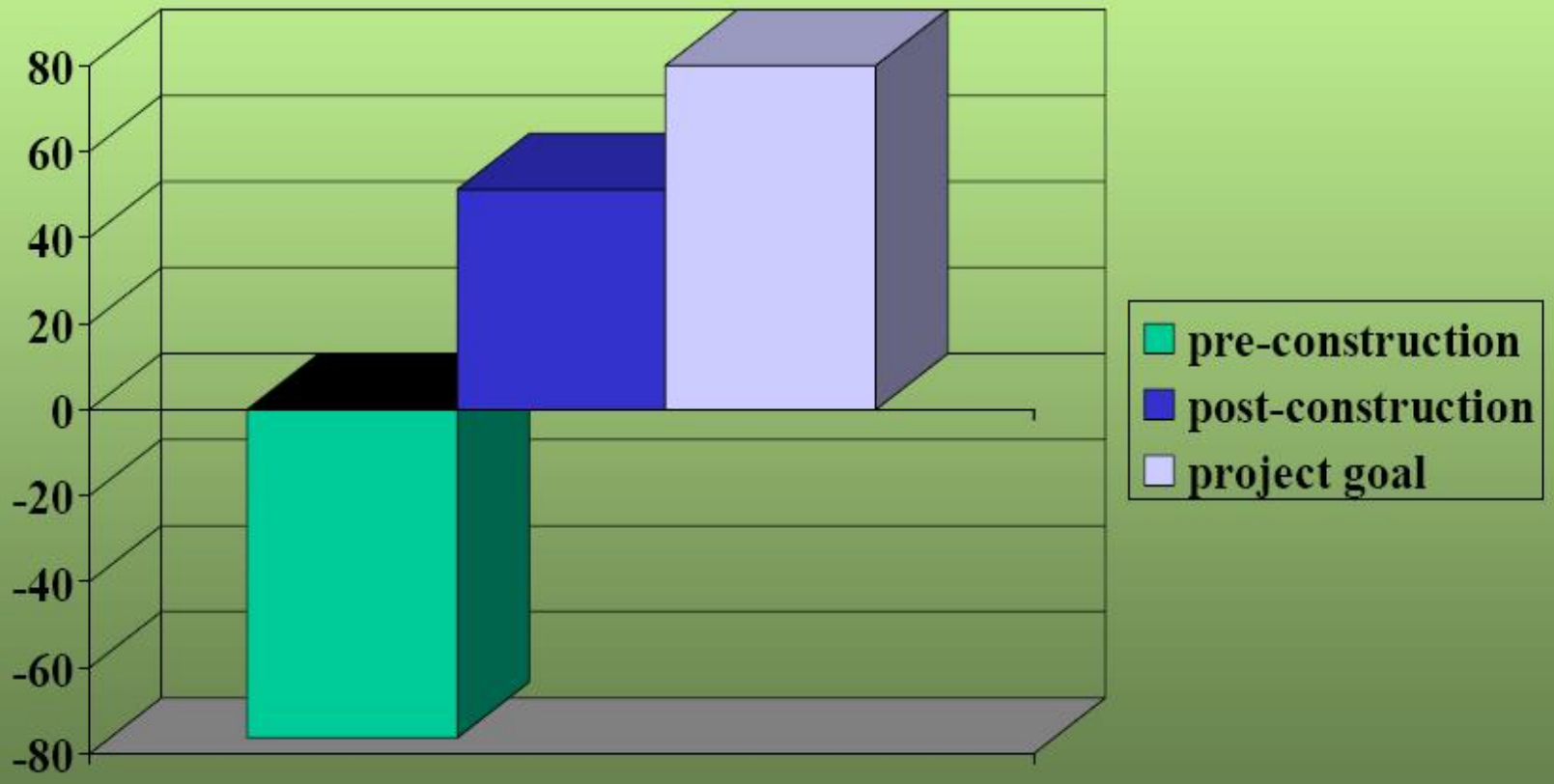
Limestone Rip-Rap Channel

Discharge Analysis (pH)

Site Location	Pre-construction (4-11-02)	Post-construction (11-17-04)
Pond 6 discharge (limestone channel 2)	6.28	6.0
Slag channel 5	6.25, 4.87, 4.64, 6.8	10.5
Pond 1 (slag channel 7)	2.99	11.0
Channel 6	4.5, 6.64	10.0
Bog discharge into slag swale	5.88	7.0
Slag Swale Outlet	---	11.0
Weir outlet	4.78	10.0
Project Outlet Channel, downgrade	3.97	9.0
Brass Road Culvert	3.97	8.0

Acidity/Alkalinity

(mg CaCO3/L)

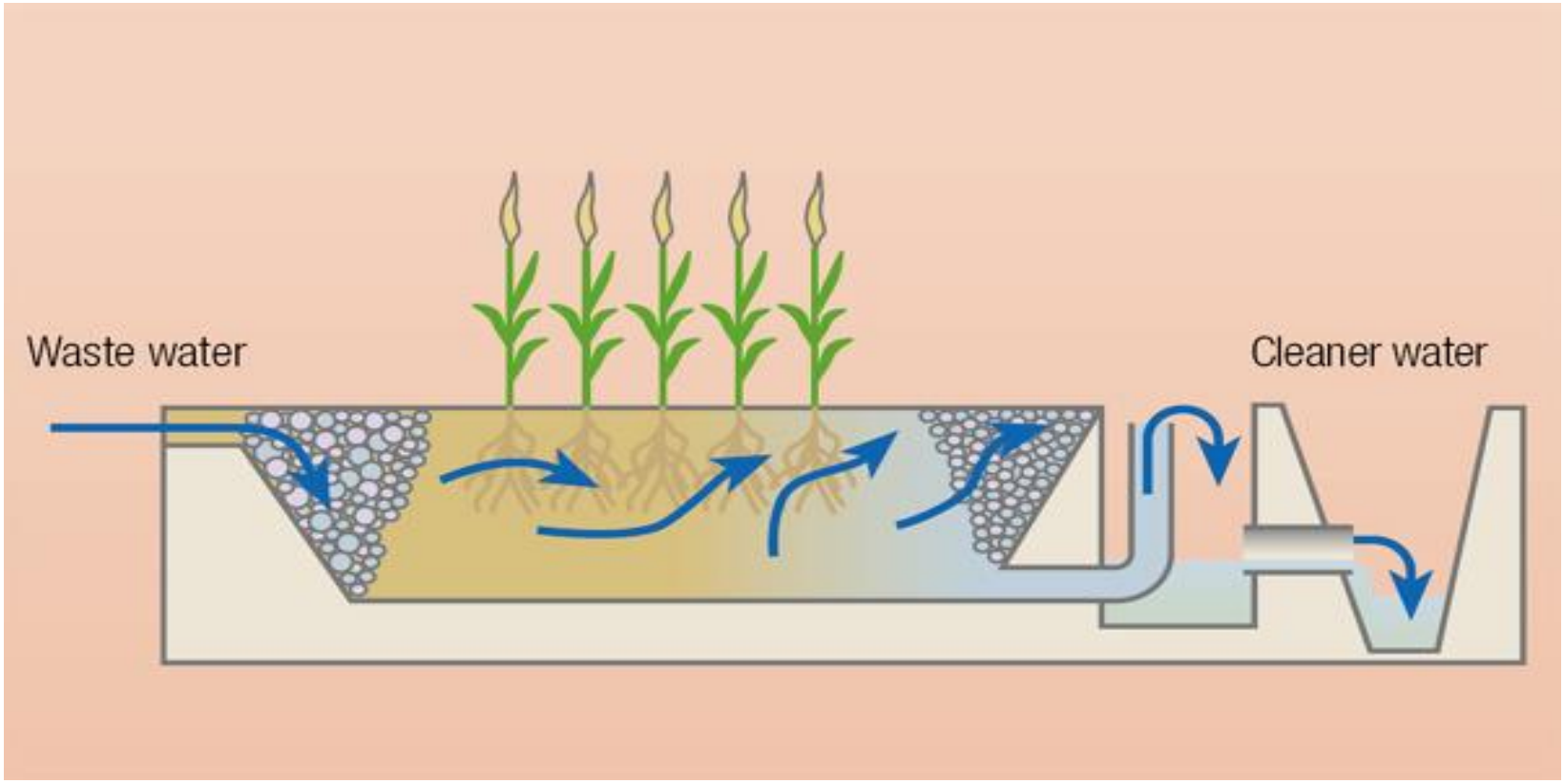



SLAG for Constructed Wetlands

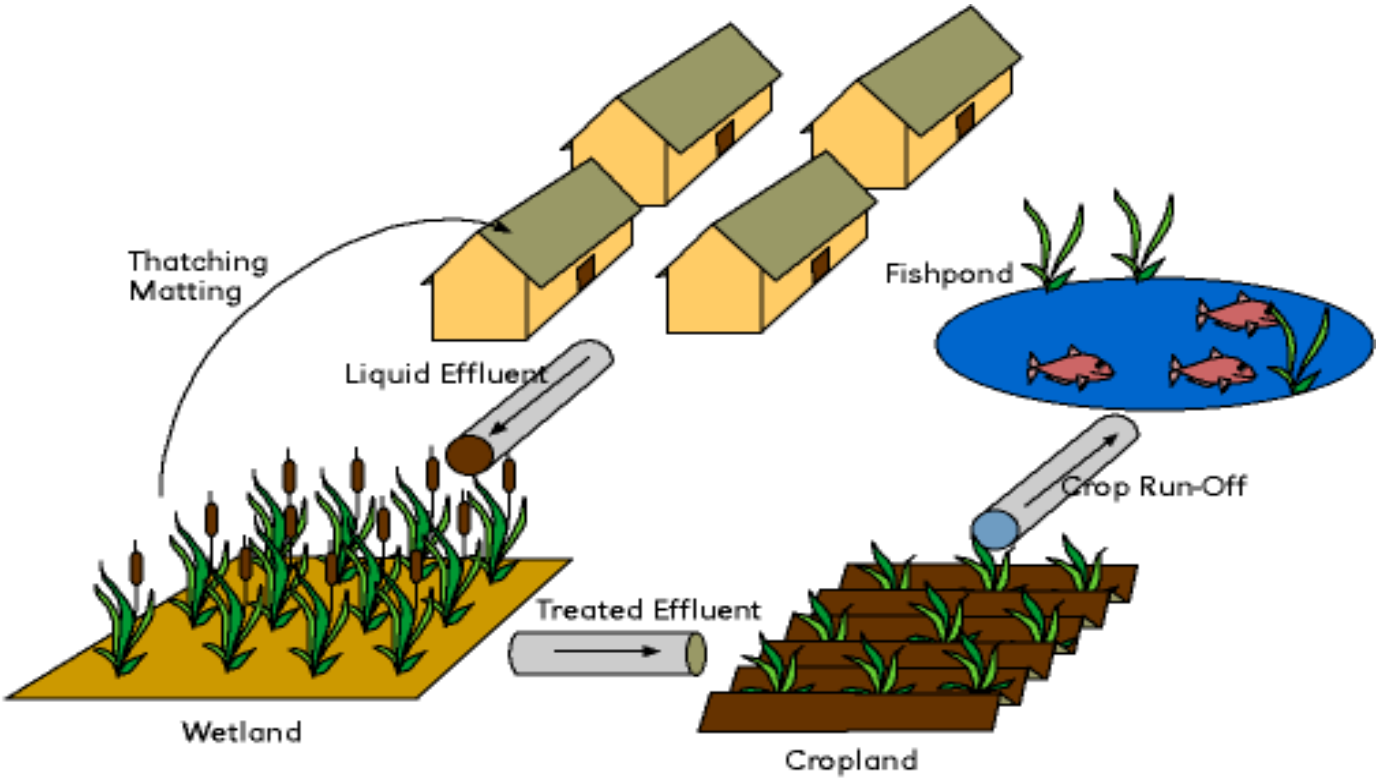
Steel Slag

Use of Steel Slag in Constructed Wetlands Technology to effect P (Phosphorus) removal.

Constructed Wetlands



Constructed Wetlands



Constructed Wetlands UKRAINE (Before)

Constructed Wetlands UKRAINE (After)

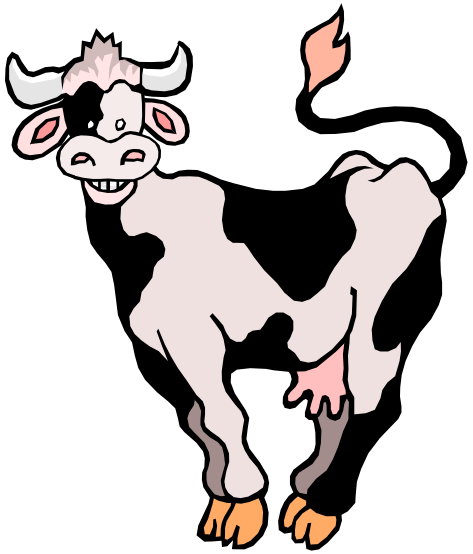
Constructed Wetlands Africa

Constructed Wetlands Nevada

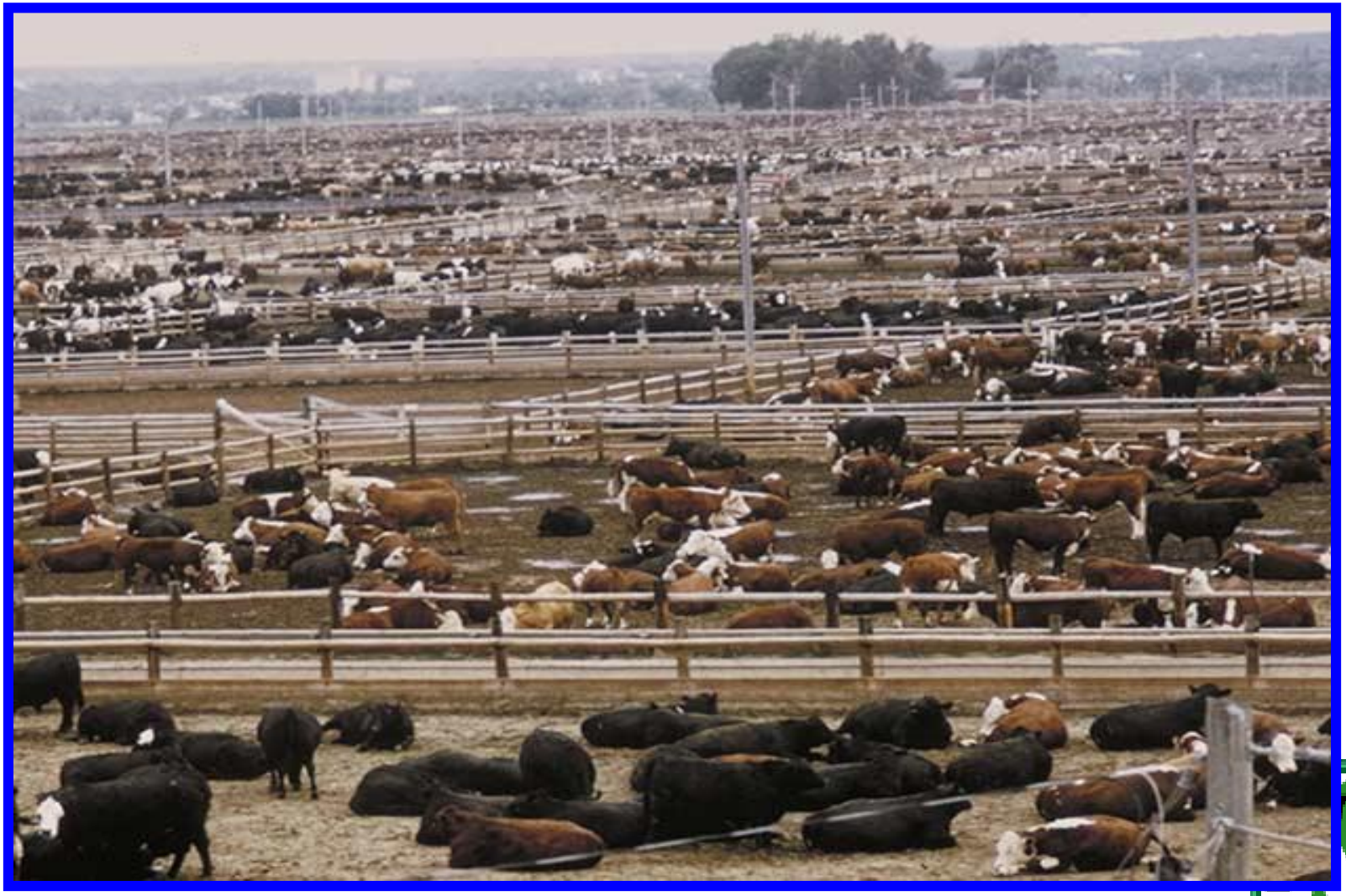
SLAG for Farm and Ranch Runoff

Steel Slag

Use of Steel Slag as a filter medium to treat water runoff from barnyards, feedlots, and milk house effluent.



Steel Slag Potential Use



Steel Slag Potential Use

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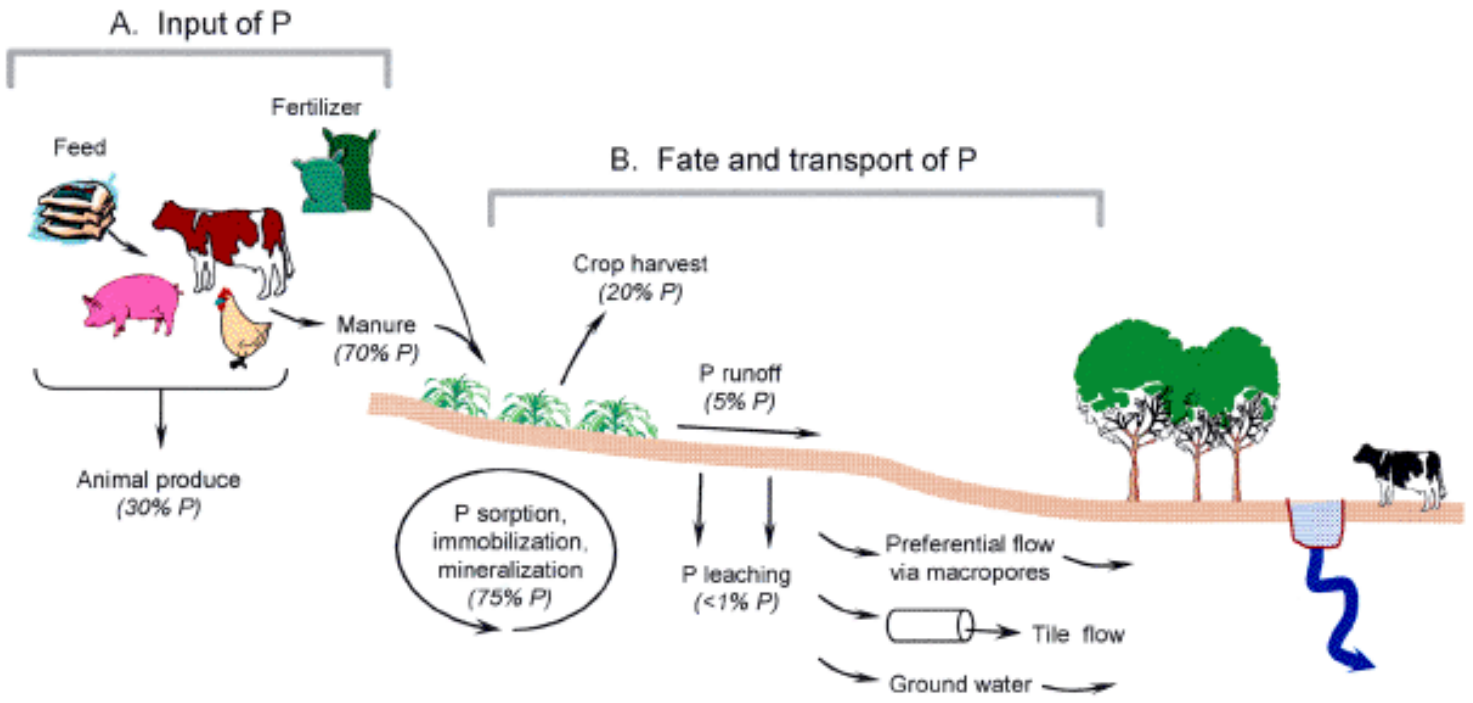

Figure 4 - Factors affecting the input, fate, and transport of P in agricultural systems. Numbers in parentheses are based on approximate farm inputs of P in animal feed and fertilizer and output in animal produce (A) and manure and fate in soils, crops, and transport in runoff (B). Adapted from Howarth et al. (2000) and Sims and Sharpley (2005).

Steel Slag Potential Use

SLAG as a "Green" Material !

- **Hundreds of years of use as an industrial co-product!**
- **A multitude of applications which contribute to its capabilities as a "Green Material"!**

National Slag Association
Founded in 1918

"The recovery and reuse of slag conserves tens of millions of tons per year of other natural resources"

American Iron and Steel Institute

SLAG & the LEED Program!

"SLAG is a recognized industrial co-product under the LEED Program!"

LEED . . . . What is LEED®?

LEED stands for Leadership in Energy and Environmental Design.

It is a green building rating system first launched by the US Green Building Council (USGBC) in 1998. The USGBC is a not for profit organization made up of companies and organizations from every sector of the building industry, who work to promote buildings that are environmentally responsible, healthy and profitable.

LEED . . . . What is LEED®?

- LEED is a third party certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings.
- LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance.
- Establishes a rating system to evaluate green construction materials and building systems.

LEED: Green Building Rating System

- Encourages and accelerates global adoption of sustainable green building and development practices through the creation and implementation of universally understood and accepted tools and performance criteria.

- Developed by USGBC, LEED is a practical rating tool for green building design and construction that provides immediate and measurable results for building owners and occupants.

LEED: Green Building Rating System

- LEED promotes a whole-building approach to sustainability by recognizing state-of-the-art strategies for performance in five key areas of human and environmental health:
  - Sustainable site development
  - Water savings
  - Energy efficiency
  - Materials selection
  - Indoor environmental quality
- Builders can obtain credits for using materials or systems which are more energy efficient in construction, utilize recycled waste materials from other industries, or result in a more energy efficient and environmentally sound building.

SLAG

"A Green Product in its own right ! ! ! "


SLAG . . . . .
A Hot Product with a myriad of uses and applications! ! ! !

SLAG . . . An Industrial Co-Product of the Iron & Steel Industry

Questions ? ? ? ?

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- **National Slag Association**
  - Website: www.nationalslag.org

SLAG . . . An Industrial Co-Product of the Iron & Steel Industry

THANK YOU ! ! ! !