RECLAMATION OF COPPER TAILINGS IN ARIZONA UTILIZING BIOSOLIDS[1]

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Abstract

There are many benefits to the utilization of biosolids (municipal sewage sludge) for tailings reclamation. Biosolids offer a cost-effective source of organics and nutrients necessary for successful reclamation; and the tailings sites offer an economical and environmentally sound solution to the disposal of biosolids. In Arizona, we are investigating the effectiveness of applying biosolids for the reclamation of copper tailings in arid environments. The primary objective is to find the appropriate application rates that: (1) meet tailings reclamation objectives; and (2) provide for an environmentally safe method of disposal for the biosolids. Rules recently developed by the Arizona Department of Environmental Quality (ADEQ) allow for the use of biosolids for reclamation. However, these rules restrict the rate of biosolids to a one-time application rate of "5X the agronomic rate" based on nitrogen, application to sites with a pH >6.5, and to slopes <6%. These restrictions do not adequately address the needs for successful copper tailings reclamation. The main objective of the use of biosolids for reclamation is to incorporate enough organic matter into the tailings to produce a "growth medium" that can sustain plant growth without the need of "topsoil".

Tests have shown that vegetation can be established and sustained on copper tailings if sufficient organic matter is incorporated into the copper tailings. Biosolids offer a viable and economical source of this organic matter. In addition, the biosolids provide the essential macro-nutrients necessary to establish a sustainable ecosystem. For the municipalities, this use of the biosolids addresses an ever-increasing problem of cost-effective disposal alternatives of the biosolids.

The results of several studies illustrate that the "5X agronomic rate" (approx. 20 dry tons/acre) is insufficient to meet copper tailings reclamation objectives and that, at rates as high as 135 dry tons per acre, there were no nitrates leaching nor heavy metal problems. Tests verify that an application rate of from 60 to 100 dry tons per acre have achieved successful reclamation.

Additional Key Words: copper tailings, biosolids, arid environment.

Introduction

There is a tremendous need in today's environmentally conscience world for the mining industry to develop more effective methods for reclamation of mining disturbances. Arizona is a leader in the nation in total mineral production, producing two-thirds of the nation's newly mined copper. One of our greatest challenges for the new millennium is to produce the domestic minerals demanded by our society while protecting the environment. Reclamation has become one of the cornerstones of modern mining. In 1994, Arizona passed the Mined Land Reclamation Act which requires reclamation of all mining disturbances on private land to a predetermined post-mining land use. In 1996, the Arizona Department of Environmental Quality (ADEQ) adopted new rules allowing the use of biosolids for reclamation for the first time. The Arizona Mining Association estimates that there may be over 33,000 acres of active mine sites that can be reclaimed with the use of biosolids (AMA, 2000).

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Recognizing that copper tailings are nothing more than crushed rock, or the parent material of soil, ASARCO Incorporated began experimenting with innovative ways to develop copper tailings into a “growth medium” by incorporation of organic matter almost three decades ago. Earlier research indicated that, if enough organic matter was incorporated into the tailings, vegetation would grow without the need of “topsoil”. Realizing that “topsoil” is not always available for reclamation, nor necessarily ecologically sound (excavating topsoil creates additional land disturbances and merely “buries” the tailing without treatment), Asarco has been trying to pursue methods of incorporating the necessary quantities of organic matter into the tailings to produce a growth medium capable of sustaining plant growth. As this early work slowly progressed, it became evident that it would take substantial quantities of organic matter for success. One of the major limiting factors that became quite evident was the economic availability of large quantities of organic matter. One obvious source of economical organic matter was municipal biosolids, or sewage sludge. The municipalities currently have a problem disposing of these wastes. The mining industry may be able to provide an outlet for large quantities of biosolids to be utilized for reclamation purposes. The use of biosolids for reclamation would eliminate the need for landfilling, or other less desirable means of disposal of the biosolids. However, existing statutory and regulatory constraints limit the use of biosolids for reclamation purposes.

The idea of using municipal biosolids for reclamation of mining wastes is not new. Biosolids have long been recognized as a beneficial amendment for mined land reclamation. The positive use of biosolids for successful reclamation goes back 25 years or more. Much of the early work involved coal spoil reclamation in the Appalachian area. Today, Sopper (1993) references 122 sites that are successfully reclaiming mine wastes with biosolids. More recently, there has been some use of biosolids for reclamation of taconite tailings in Minnesota (Norland, et al., 1992), copper tailings in British Columbia (Wilson, et al., 1993), and metal tailings in Idaho and Utah (Brown, unpublished, 1997). Our work in Arizona is the first to look at biosolids for reclamation of copper tailings in the arid southwest.

To date, research involving biosolids for reclamation has concluded that many of the concerns over the use of biosolids are unsubstantiated (Sopper, 1993). The major concerns over the use of biosolids for mine reclamation include:

- leaching of nitrates
- heavy metal contamination from the biosolids
- acidic conditions mobilizing heavy metals

The major benefits of using biosolids for reclamation include:

- improvement of tailings fertility
- increasing tailings pH
- increasing vegetative establishment without topsoil

Biosolids provide a residual fertilizing action that is superior to chemical fertilizers over time. Sopper (1993) cites little depletion of nutrients over a decade or more, and there is an increase in plant productivity. There have been no problems with heavy metals or pathogens. The research done to date indicates there is no evidence of nitrates leaching, or any threats to grazing animals or wildlife on the biosolids tests. Sopper (1993) also cites that biosolids can increase the pH of the mine wastes (in one instance from a pH of 4.2 to 7.2 with 8 inches of biosolids incorporated into the top 12 inches of spoil). Biosolids have proven better than lime at raising pH since lime will oxidize over time. The biosolids chelate and bind, or complex, the pyrites of the mine wastes and tie up heavy metals. There is a marked increase in organic matter and an increase in microbial activity with an increase in nutrient cycling and decomposition of organics. High levels of biosolids will improve the physical characteristics of the mine wastes; such as decreasing bulk density, improving water holding capacity, and increasing infiltration. Biosolids also improve hydraulic conductivity and water saturation percentage, increases cation exchange capacity; and improves surface temperatures. The increased CEC helps to immobilize heavy metals.

Copper tailings are unique, unlike any natural soil. The tailings are totally devoid of organics, have extremely low levels of N and other essential macro-nutrients, and are sometimes acidic in nature. Tailings also have total heavy metals far in excess of any biosolids (especially those of “Class A or B” quality). There are no clay minerals in the tailing, and they do not behave like any natural soil. Generally speaking, the tailings will "consume" large quantities of N, and, if the pH can be raised to 5.0 or higher, any heavy metals are immobilized.

To achieve successful reclamation of copper tailings, enough organic matter must be incorporated into the tailings to produce a change in the physical texture and structure of the tailings. Earlier tests on Asarco's tailings have shown that a mixture of 15-25% biosolids will yield an acceptable level of reclamation success. To reach this goal and to sustain sufficient plant growth, the rate of biosolids application may have to exceed the agronomic rate of N by as much as 25X.

In 1994, ADEQ started developing new rules for the application of biosolids for reclamation. At the time there wasn't any information available that was specific to Arizona, nor to copper tailings reclamation, which might provide guidance in the development of these new rules. Among some of the major problems in these new rules are the stipulation that application rates of biosolids not exceed "5X the agronomic rate" of N, that biosolids may only be applied to sites with a pH of 6.5 or greater and with slopes of less than 6%. These restrictions were placed in rule to address the concerns of ADEQ about potential excess nitrates leaching into the groundwater or running offsite, and the possible mobility of heavy metals.

Working with ADEQ, the Arizona mining industry has conducted several tests to assist in the development of rules that would appropriately address the needs for tailings reclamation while protecting the environment. The primary objectives of these tests are to determine the appropriate rate of biosolids application for successful tailing reclamation, and to collect quantifiable data on the results.

The Arizona mining industry is looking for an effective and economical source of organic matter for reclamation of copper tailings. The primary reclamation objective is to establish a permanent, self-sustaining vegetative ecosystem on the copper tailings which will stabilize the site and provide for the productive future use of the site, such as wildlife habitat and limited livestock grazing. Building the tailings into a "soil" with massive quantities of organic matter may be more ecologically sound than merely burying the tailings with "topsoil". There are many sites where "topsoil" is unavailable or would require even more ecological damage by requiring further land disturbance. Also, if this technique can be proven successful, we may be able to do more reclamation of sites such as "abandoned" mines.

ADEQ is concerned with the environmental impacts of the use of biosolids. Rules for biosolids application have to be developed that will ensure the protection of human health and the environment. Among the chief concerns of ADEQ are the potential release of nitrates and heavy metals. They are concerned that heavy loading of nitrogen rich biosolids may release excessive amounts of nitrates. Hence, the limits of biosolids application to no more than a one-time application rate of "5X the agronomic rate" of N, and restriction to slopes of less than 6%. They are also concerned that the heavy metals found in some biosolids, especially at high application rates, may contaminate the site and cause problems if mobilized by pH's less than 6.

<u>Arizona's Experience with Reclamation of Copper Tailings Utilizing Biosolids</u>

In 1994, Asarco cooperated with Chemical Lime Co. (Chem-Lime) in conducting a column leach study on the leachate from lime-treated municipal biosolids mixed with acidic copper tailings. The results of this test indicated that a rate of 150 tons/acre of lime-treated biosolids dramatically improved the tailings with no environmental impacts or leaching of metals, etc. The pH of the tailing rose from 3.4 to 9.7, with a corresponding rapid drop in heavy metals in the leachate. Total Kjeldahl nitrogen was not analyzed, but nitrates were below detectable levels (Curtis 1994).

In 1995, Asarco initiated a greenhouse pot study conducted by Plant Health Care Inc. The biosolids used in this study were not lime stabilized. The biosolids were mixed with acidic copper tailings at concentration rates of 10%, 15% and 25%. The 15% and 25% proved best. The pH rose from 3.5 to 5.2 at 15% biosolids and to 5.9 at 25% biosolids. The biosolids also significantly improved the fertility of the tailing. The addition of biosolids significantly increased biomass production from less than 3/4 gram to over 7 grams/pot of forage. Further, the addition of vesicular-arbuscular mycorrhizal fungi (VAMF) significantly increased biomass production in all biosolid treatments to as much as 10 grams/pot (Marx, 1996).

In 1996, a full-scale test was conducted on acidic tailings using 4 different application rates of municipal biosolids. This test is designed to evaluate the incorporation of 20-30% solids Class "B" biosolids into the tailings. These biosolids are readily available from the wastewater treatment plant, can easily be transported, and require no special handling. These acidic tailings were chosen as representative of a more challenging site and, if successful, this technique could be applied to many "abandoned" mine sites.

The biosolids were incorporated into the tailings at "5X the agronomic rate" of N (approx. 20 dry tons/acre), 15% or 2 inches of biosolids (approx. 70 dry tons/acre), 25% or 3 inches (approx. 100 dry tons/acre), and 30% or 4 inches of biosolids (approx. 135 dry tons/acre). Because these were older tailings, the pH was in the 3-4 range. Due to this slightly acidic pH and the concerns of ADEQ over the leaching of nitrates, some of the test plots were treated with lime and others with greenwaste.

Prior to application of the biosolids, the greenwaste was applied to designated plots at approximately the application rate of biosolids (1/2 inch for the 20-ton rate; 2 inches for the 70-ton rate; 3 inches for the 100-ton rate; and 4 inches for the 135-ton rate). Certain plots were also treated with lime at a rate of 8.8 tons/acre (Bengson, 1999).

The test plots were then broadcast seeded with, first, a mixture of annual cool season grass & forb species and, later, with a mixture of warm season perennial grasses. Irrigation was added to ensure adequate moisture for germination and plant production and to simulate an extremely wet climatic cycle. Irrigation was minimized to only supplement the natural rainfall. Irrigation and rainfall totaled 19.67 inches for the two growing seasons. Evaporation for the two seasons totaled 117.5 inches (Bengson, 1999).

The results of this test indicated that there were no nitrates leaching below 12-18 inches. Although there was an initial spike of ammonia and nitrate at the surface of the heaviest biosolids plots (135 tons/acre), this did not persist and there were no nitrates detected at depth (Bengson, 1999). After more than two years, there is still less than 20 ppm nitrate N at depth under the heavier application rates of biosolids. The greenwaste apparently had some effect on promoting microbial N immobilization and slowed the mineralization of organic N, but did not make a significant difference in leaching. Others (Wilson, et al., 1993) show similar results. Sampling indicates little statistical difference in available metals with increasing biosolids application. According to research by Sopper (1993), plant metal concentrations generally increase with biosolids application, but remain below phytotoxic concentrations and decrease over time. Similar research on copper tailings elsewhere reported diluted levels of available copper with addition of biosolids (Wilson, et al., 1993). The biosolids at all levels of application initially raised the pH to close to 6. After two years, the 70 and 100 dry tons/acre of biosolids alone still maintains a level near pH 5 & 6. The greenwaste did not appear to make any significant difference in pH. The lime-treated plots did show improved pH, but still did not maintain levels above pH 6.5.

As for reclamation success, the biomass production showed a positive effect of additional biosolids. The "5X agronomic rate" did not provide sufficient plant growth no matter which additional amendment was used. The biggest contribution of the greenwaste to biomass production was the additional shrub and tree species that germinated from the greenwaste. This test indicates that, at rates of 70 to 100 tons of biosolids/acre, successful reclamation can be achieved with no problems of nitrates leaching, heavy metal contamination or other environmental concerns (Bengson, 1999).

Another test was conducted on neutral copper tailings. This test looked at the application of dried biosolids (70% solids) at rates of 30, 60 and 90 dry tons/acre (Thompson and White, 2000). Additionally, 100 tons of greenwaste were added to some of the plots. This provided a carbon to nitrogen ratio of 50:1. This latest test had similar results of the first test. The very best reclamation success came from the plots treated with 60 tons of biosolids and 100 tons of greenwaste/acre. However, the biosolids alone at 60 tons/acre was also successful in total biomass and % groundcover (Thompson and White, 2000). The biggest contribution of the greenwaste in this test proved to be moisture retention. These tests also included irrigation as a supplement to rainfall.

As with the previous test, this test proved there was little evidence of significant nitrate below 30 cm and none at 120 cm (Thompson and White, 2000). There was also no evidence of heavy metals increasing significantly.

Interestingly, there was some increase in nitrates with the greenwaste amendment in the surface 30 cm but, again, none below 120 cm (Thompson and White, 2000).

A third test was recently conducted utilizing dried biosolids mixed with soil (from an evaporation pond) at a rate of approximately 100 tons/acre. This material was incorporated into the surface on approximately 5 acres of neutral tailings. Here the test was looking at microbial action. There was very little evidence of microbial activity in the tailing prior to treatment. The biosolids were, of course, extremely rich in microbes. The results indicated an approximately 10,000% increase in microbial activity. The tailing went from a MPN count of $5.4X10^3$ to $2.3X10^7$ with a very diverse microbial population (Pepper, 2000). This test showed no problems with pathogens such as Salmonella, Enterovirus, or Microsporidia. As for reclamation success, the average ground cover was measured at 18% which is very good especially since this test was conducted without irrigation and during two of the worst droughts seen in southern Arizona.

The question now is, where do we go from here? We are in the process of working with ADEQ to develop a rule change. This will allow the Arizona mining industry to investigate long-term contracts with municipalities for the disposal of biosolids. The industry has estimated that there may be over 33,000 acres of mining sites available for reclamation utilizing biosolids in the next ten or more years. If the rules can be changed from the limit of "5X the agronomic rate" and not limited to sites of pH >6 and slopes <6%, we can begin to accomplish a great deal of successful reclamation while properly disposing of municipal biosolids.

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