Reclamation of the Nanfen iron mine tailings deposit, Benxi Government, Liaoning province, China

REPORT OF A SENIOR EXPERT CONSULTANCY OF R.J.OOSTERBAAN, AGRICULTURAL ENGINEER, UNDER PUM PROJECT 42806 M CN, THE NETHERLANDS, 19 to 29 AUGUST 2007

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Interpreter Ms. Jiu Fei in the foreground of the mine tailings deposit.

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The top of the dam containing the tailings deposit seen from Nanfen city

I. Terms of reference

1) To reselect the tailings for multipurpose use and bring no secondary pollution to the environment. That is to recycle the waste products left after the extraction of non-ferrous metals and ferrous metals from the tailings with no or fewer discharge.
2) To reclaim the land where the tailings storage stands.
3) To grow cash crop in the reclaimed land and organize relevant technological training.

Comments on terms of reference

Duty 1) was already carried out previously by PUM expert Leo Stephan in 2006.
Duty 2) is subject of this report.
Duty 3) it was concluded in duty 2) that reclaiming the entire tailings deposit for cash crop growing land is not feasible.

View of Nanfen city from the top of the dam containing the tailings deposit

II. Introduction

At the request of Mr. Amin Lin, director of the Nanfen Peoples Government (NPG) of Benxi City, Liaoning province, China, the PUM organization of senior experts, The Netherlands, deputed me to advise on the reclamation of the reclamation of the tailings deposits of the Nanfen iron mine. I visited Benxi in the period of 19 to 29 August 2007. A month prior to my arrival I had sent a prelimary program proposal including background information on the reclamation possibilities. The program was translated into Chinese.

The tailings deposit is property of the Benxi Steel and Iron Real Estate Company (SIREC), a central state enterprise. The responsibility for the reclamation of the tailings deposits rests with the company.

Near Nanfen city, a 130 m high dam has been constructed in a valley to contain the wastes (tailings) of the iron enrichment (or beneficiation) plant, which separates the iron from the non-usable minerals of the ore. The tailings are transported as liquid slurry through pipelines and deposited behind the dam. In the deposit, the slurry dries out and a cover of fine sandy minerals remains. The minerals are utterly infertile and have no ability to hold and store rain water, so the surface layers of the deposits are dry.

The tailings deposit is now full. It covers an area of 122 ha with an average thickness of 40 to 60 m. The deposit has been closed since a year and no more deposits occur. At present the surface of the deposit is still barren.

Top of the dam containing the tailings deposit that can be seen to the left.

I was informed that it is in the interest of Nanfen district that the tailings deposit is reclaimed, meaning that a plant cover is established to eradicate the dust storms over the city and to have a recreational park for the inhabitants of Nanfen city.

On 22 August a meeting was arranged by Mr. Amin Lin with and Mr. Jiang Yong Sheng, manager of SIREC, and me. I was given the opportunity to provide a brief overview of the reclamation possibilities (Appendix 1.) I was assisted by Ms. Jiu Fei, interpreter, who had previously translated the contents of my discussion notes into Chinese.

Mr. Amin Lin explained the interests of the Nanfen district to eliminate the dust storms and to have a green park.

Mr. Jiang Yong Sheng stressed his intentions to cover the deposit with soil scraped from new urban developments and from the opening of new mining pits, and start an economically profitable exploitation using high value crops.

I mentioned the fact that, worldwide, no economically profitable developments with a new soil cover trucked in from elsewhere have been achieved, while ecologically sound reclamation techniques, like hydro-seeding of pioneer vegetations, were successful in creating environmentally attractive green areas (see the Appendix) at relatively low cost.

An impression of the vast expanse of the desolate tailings deposit.

III. Reclamation of Nanfen tailings deposit

This section contains parts of the provisional work plan submitted by me a month before arrival in China. It was translated into Chinese and extensively discussed with staff of the Nanfen People's Government of Benxi City on 23 August.

Metal mine tailings deposits have **no** fertility at all. I addition, the have **no** water holding capacity so that rain water quickly disappears into the underground and the upper layers remain **dry**.

The deposits of iron mine tailings in general and of the Nanfen iron mine in particular contain low amounts of heavy metals posing no danger to the environment.

Due to lack of nutritive elements and unavailability of water it is difficult for plants to establish themselves on the surface of the deposit.

The reclamation of the deposit must therefore be one by
A - applying a thick fertile soil cover
B - hydro-seeding of local drought resistant pioneer plants that have low fertility requirements
C - planting shrubs and trees with their roots in bags filled with fertile soil
D - using a combination of these measures

A. SOIL COVER

The application of a soil cover over the entire area of the tailings deposit was ventured nowhere in the world so far. The main reasons are:
- it is difficult to obtain enough soil from elsewhere without harming the area from where it is taken
- it is costly and energy consuming to transport the soil and spread it out

Fertile soil may be available from new urban developments, but the quantity is usually so small that only a fraction of the tailing can be treated.

Top soil from newly excavated mine pits is usually thin and does not provide much volume per ha and it is needed to restore the pit itself after the ore has been removed.

Yet, it might be possible to apply soil, if suitably available, to a **fraction** of the tailings deposit for special purposes such as the production of valuable agricultural crops, the planting of trees in soil-filled holes, or the establishment of a park.

B. HYDRO-SEEDING

Hydro-seeding is the application of a mixture of
1 - seeds
2 - water
3 - organic matter
4 - fertilizer

1. Seeds

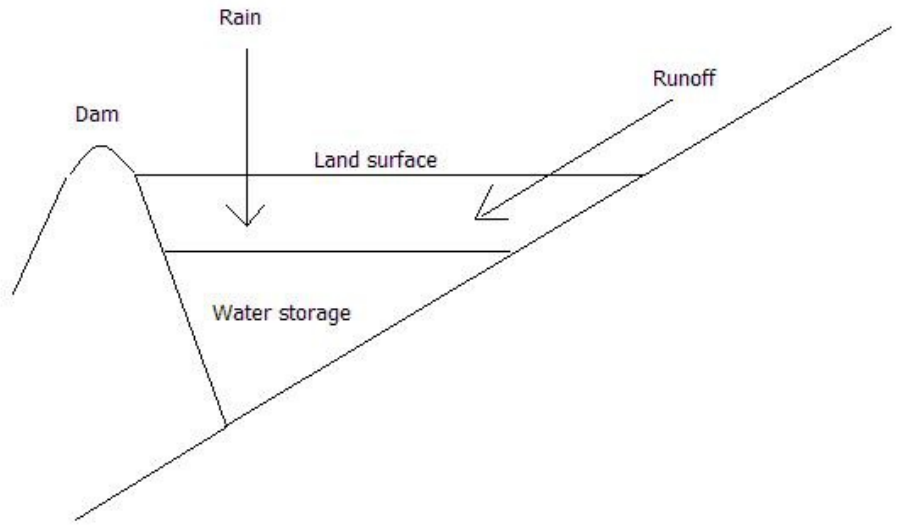
There is no known worldwide standard available for the selection of the proper seeds, as this is dependent on the local ecology. One will have to consult biologists, ecologists and forestry specialist to select local or regional species (e.g. grasses) that are able to survive in poor soils under drought conditions. It is advised to use natural plant species that are present in the region.

2. Water

Water can usually be found in a nearby watercourse or river. In addition, it will be necessary to consult a (geo)hydrologist to set up a water balance of the tailings deposit itself.

The **rainfall** percolates quickly through the soil (because the soil has a very low water holding capacity) and is stored in the underground. Further, **runoff** from the watershed in which the tailings deposit is situated will also enter the groundwater reservoir.

The water balance serves the purpose of determining the water resources available in the area. The available water may be pumped from the underground by wells and used for preparing the hydro-seeding mixture and for irrigation of the vegetation to overcome drought stress.



Schematic cross-section through the tailings deposit showing an underground water reservoir replenished by rain and runoff.

3. Organic matter

Organic matter may be obtainable from a variety of sources. For example:
a - City waste and city sewerage systems
b - Farm produce (hay, straw, other produce) and waste
c - Waste of timber processing plant (bark, wood chips)
d - Waste of paper mills, carton industry
e - Waste of textile plants using linen, cotton and other natural materials
f - Other sources, like fallen leaves etc.

The organic matter serves the purpose to provide a fertile environment to the seeds, to hold moisture, and to retain the fertilizers.

Larger lumps of organic matter, like maize stalks (maize is grown around Nanfen extensively), may have to be shredded.

It is recommended to search the internet with keywords like "iron mine tailings", "hydroseeding tailings reclamation", etc., to find more information on the various techniques and the organic matter used in the world.

4. Fertilizers

Fertilizers may be the standard NPK (Nitrogen, Phosphorus, Potassium) fertilizer used in agriculture to the standard amounts recommended for agriculture (say 100 kg/ha). Also animal dung can be used.

5. Application of hydro-seeding

The substances used in hydro-seeding can be mixed into a sludge (thick "soup" or "porridge") and spread out evenly over the land to a thickness of a few mm.

In developed countries there is special machinery available for this purpose, but one can also apply the mixture by hand from wagons pulled by tractors, or the wagons may be equipped with a large valve.

Biologist can determine the best seeding season.

Hydro-seeding usually results in a vegetation cover of less than 100% in the first year. Therefore, results of the application of the hydro-seeding needs to be **monitored**, and a second seeding in part of the area may be required to obtain full coverage. It could be that one or more of the components of the mixture need to be adjusted.

It is possible to try different mixtures in different parts of the area according to the availability of the components. This also gives opportunity to **evaluate** the potential of the various mixtures.

The total area of the tailings deposit may be divided in sub-areas to be reclaimed with the hydro-seeding technique in **phases** according to the hydro-seeding capacity employed.

It may be advisable to start with a small pilot area of 1 to 10 ha.

*It is recommended to search the **internet** with keywords like "iron mine tailings", "hydroseeding tailings reclamation", etc., to find more information on the various techniques used in the world.*

C. TREE PLANTING

Tree planting can be done in dug holes filled with fertile soil and/or the mixture used in hydro-seeding. The tree seedlings are to be planted with their root systems contained in bags filled with soil.

Also smaller shrubs can be planted that need smaller holes and root bags. The trees and shrub species will have to be selected with the advice of biologists, ecologists and forestry experts to make sure they are drought resistant and survive in low fertility soils.

It would be advantageous to include trees whose fruits attract birds, because bird droppings can contain fertilizer and seeds giving vegetation enhancing the bio-diversity of the area.

D. USE OF THE AREA AFTER RECLAMATION

After reclaiming the Nanfen tailings deposit, parts of the area can be further developed for different purposes:

a - ecological zone
b - recreational area
c - city park
d - productive agricultural area
e - housing complexes
f - At present a few minor lakes are already present in the Nanfen tailings deposit. This indicates the possibility to create natural lakes. If necessary, the underground water resources can be used to maintain the water level in the lake

IV. EXAMPLE

Example of the reclamation of iron mine tailings deposits in Wisconsin, USA

[Source: James Ludwig, Ph.D., Thomas Hunt, Ph.D., and Jack Broughton, Badger State Pioneers Mine Reclamation Techniques, Applied Ecological Services (AES), Inc.]

This source was found on the internet.

Innovative techniques, such as using wetlands for biofiltration, were a large part of the Flambeau mine reclamation design completed in 1998 by AES.

Major successes with native species were realized at the Jackson County Iron Mine where AES began experimentation with native prairie species in 1977, and with live-staking brushy species on tailings in 1980. This mine closed temporarily in 1983, and permanently in 1986. Between 1984 and 1988, AES restored the site's 312-acre tailings basin to a dry prairie community by seeding directly into the tailings. Nearly 620 acres of the waste rock dumps were shaped and hydro-seeded with native species between 1985 and 1990. And in 1991-92, another 43 acres were covered with sandy soils and restored to prairie on what had been the mine's operating plant site.

In all, 1,340 acres were restored to native prairies, making the former mine site the largest prairie restoration in the state of Wisconsin. The restoration created a planting that allowed for gap phase invasion by native plants from the surrounding pine/oak barrens.

In fact, the restoration has proven to be so attractive that the site has been transferred to county ownership and developed into the highly popular Lake Wazee recreational area. The park now features a 114-acre, 385-foot deep lake on the site of the old mine pit, with a productive trout fishery, a premier scuba diver training site, swimming beaches, and hiking trails and wildlife areas on the restored mine. Lake Wazee has become one of the most popular regional parks in central Wisconsin, and fills a need for high quality, water-based recreation in an area of the state with few natural lakes.

V. Acknowledgements

Gratefully I acknowledge the efficient guidance and great hospitality offered by:

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I would also like to thank the interpreter Ms. Jiu Fei who made effective communication between the English speaking expert (with a Dutch accent) and the Chinese speaking leaders and officials smoothly possible.