

Pen Balls and Feathers help Gold Miners fight Mercury and Poverty

Robin Grayson MSc

Eco-Minex International Ltd.,
Apt.14, Bldg. 40, 1/40000 Microdistrict, Sukhbaatar District, Ulaanbaatar 210644, P.O.B. 242, Mongolia.
E-mail: emiweb@magicnet.mn

About the author



Robin graduated in Geology and Zoology from Manchester University in 1970 where he completed a Masters Degree in Geology before lecturing at Wigan Mining College for ten years. Robin is a specialist in placer gold and ecology and is currently compiling *Best Available Techniques (BAT) for Placer Gold Miners*. He is known as Stepegold on the famous Alaska Gold Forum (<http://bb.bbboy.net/alaskagoldforum>).



Purpose of study

Pen balls look set to invigorate research into gravitation settling and make affordable experiments on particles as dense as native gold.

For centuries, gold miners have preferred sluices to catch placer gold. In spite of innovations such as centrifuges, they prefer the sluice - cheap to make, easy to use and boasting an unrivalled concentration ratio.

Yet sluices lose most of the fine gold! Now miners can put this right, aided by pen balls. Success will help to eliminate mercury and boost profits, pulling millions of artisanal miners out of poverty and will increase the efficiency of placer mining companies.

Even cleaning up the gold concentrate for sale need not use mercury – sorting with a bird feather is shown to be easier, quicker and cheaper than using mercury.

Figure 1. artisanal miners catching 'lost' gold

Rear end of a large Soviet bucket-line dredge, one of five launched since 1994 in the Zaamar gold field of Mongolia. The design predates the 1988 Soviet ban on mercury in placer gold recovery. Three hundred artisanal miners are re-washing its tailings to recover some of the gold lost by the on-board wash-plant of this dredge. (photo: Gerrit Bazuin)

Contents

Purpose of study	42
1. Introduction.....	43
1.1 Catching gold should be easy – it isn't	43
1.2 The problem.....	43
1.3 Improving large sluices.....	43
1.4 Improving small sluices.....	43
2. Quest for the perfect tracer	44
2.1 Gold as tracer.....	44
2.2 Lead shot as tracer.....	44
2.3 Tungsten powder as tracer.....	44
2.4 Pen balls as tracer	44
2.5 Turning junk into tracers.....	44
3. Outcompeting mercury.....	44
3.1 Mercury in the final clean-up.....	44
3.2 Feathers can defeat mercury.....	45
4. Discussion.....	45
5. Acknowledgements	46
6. References.....	46

1. Introduction

1.1 Catching gold should be easy – it isn't

Catching gold by simple gravitational devices should be easy, gold being so dense. But it is difficult!

Worldwide hundreds of tons of placer gold evade capture by gravitational wash-plants. As early as 1995 losses of placer gold in Mongolia were estimated to be 50% of that mined [1] and over the last decade the 'lost gold' probably exceeds 100 tons. With a current value in the order of 2.5 billion USD - a huge sum for a poor country of 2.5 million people. A seemingly avoidable loss, as most is vented through the rear of gravitational wash-plants (Fig.1) [2,3].

Getting gravity to recover gold more efficiently isn't just about making placer mining companies richer and filling State treasuries. It's about putting cash into the pockets of poor people. From the Gobi Desert to the Amazon jungle, millions of artisanal miners toil to recover gold. Artisanal miners include some of the world's poorest and most marginalised communities, for these days gold rushes are driven by poverty - a far cry from the novice miners who sought their fortune in the historical gold rushes of California, Yukon, Alaska, New Zealand, Australia, and elsewhere.

But using gravity better isn't just about generating more cash and alleviating poverty, it's about combating mercury. Mercury was banned from placer mines in the former Soviet Union and Mongolia, and is highly controlled in the placer mines of North America and Australasia. Yet an estimated 1,000 tonnes of mercury a year are emitted into the environment by misuse by artisanal gold miners [4]. Most are engaged in recovering hard-rock gold but many are placer gold miners. Mercury is widely used illegally but unstoppably in thousands of artisanal placer mines in South East Asia, South America and Africa. Fuelling mercury misuse is frustration at the oft lacklustre performance of gravitational methods such as panning and sluicing, for which mercury amalgamation is a quick remedy [5]. Improving mediocre pans and sluices to out-compete mercury would safeguard the health of millions and sharply cut toxic threats to the environment.

Exacerbating the problem is a glut of cheap mercury worldwide triggered by the moral hazard of the European Union in eliminating mercury from its chlor-alkali industry on grounds of toxicity yet leaving the door ajar for export of mercury to the developing world where it is bought at a depressed low price by artisanal gold miners [6]. For instance in 2005 Brazil imported 43.3 tons of mercury, of which 26.9 tons came from Spain and 6.9 tons from the United Kingdom, mostly destined for use by artisanal gold miners yet implausibly labelled for use in dentistry [7].

The challenge is how to improve the effectiveness of cheap sluices and pans to recover gold by gravitational means. Success would enable sluices to out-compete and quickly eliminate mercury in placer gold mining and even cut mercury use in hard-rock gold recovery. This paper focuses on a prerequisite to success, the search for a cheap and simple tracer for testing the performance of sluices and pans, and identifies pen balls as the most promising tracer for worldwide use. The paper then draws attention to the successful use of a feather to clean the final gold concentrate prior to smelting without any need to resort to mercury at all.

1.2 The problem

Every placer miner can attest to the curious fact that gravitational recovery of gold is difficult - flattish particles glide and refuse to settle [8]; tiny particles remain suspended in agitated water and "flour" gold is hydrophobic enough to float to freedom [9]. The ubiquitous pan and sluice often lose as much gold as they catch. Of course centrifugal devices do better, but artisanal miners prefer cheap simple devices whose shortcomings are offset by adding mercury [10]. Even placer mining companies show a marked worldwide resistance to using a fine gold recovery system such as centrifuges, jigs, spirals and cones, not only grounds of cost and operational complexity but also because the basic sluice achieves an unrivalled concentration ratio.

1.3 Improving large sluices

Only in the 1980s came proper understanding of how a sluice actually works, by Canadian funded research in the Yukon goldfield assisting local economic development. Poling and Hamilton [11] observed Plexiglas-sided sluice boxes and used placer gold particles as tracers, as did Clarkson and Peer [12] who also used irradiated placer gold as easily detected ¹⁹⁸Au radiotracers. Known as "the Yukon tests", the findings revolutionised North America's placer industry, boosting gold recovery and profitability. For the first time, tuned sluices could consistently recover more than 90% of gold down to 0.2mm diameter. Success achieved, funding ceased.

That's a pity, for the same sluices still lost more than 50% of finer gold.

What is going on? The Yukon sluice tests were tailored to scientific recovery of gold particles bigger than 0.2 mm as this is the normal size of placer gold in the Yukon [13,14]. The collective wisdom of mineral separation scientists remained that a sluice was incapable of recovering fine gold, a view not dispelled by sellers of jigs and centrifuges. Some placer mining companies turned to jigs and centrifuges to recover fine gold, while artisanal miners persisted with the sluice and worldwide their improper use of mercury skyrocketed.

In response, for 20 years international projects have promoted safer use of mercury and recycling it via retorts, rather than seeking to improve sluices to out-compete mercury to eliminate it. While some projects succeeded in vastly improving large artisanal sluices, as exemplified by Styles, Simpson and Steadman [15] in Guyana, little effort has been made in such projects to push sluices beyond the 0.2mm threshold achieved in the Yukon tests. Mercury remains unchallenged, even though 30 years ago soviet workers showed mercury to fast decline in effectiveness below 0.1mm to recover only 65% of 74μ gold [16].

Gravitational sluices should be able to out-compete mercury, for "effectively recoverable" cassiterite SnO₂ is as mere 20μ yet its specific gravity is 6.8-7.2 compared with placer gold's 15.0-19.3. Accordingly Wang and Poling [17] invoked Stokes Law to suggest "effectively recoverable" placer gold should be a mere 12μ nominal diameter - far smaller than the 0.2mm achieved consistently in the Yukon tests. On this basis, out-competing mercury by improving sluices to recover 90% of >74μ gold looks simple, but deceptively so, for Wang and Poling [17] stress that placer gold is more difficult to capture due to it being hydrophobic, often porous, and commonly flattish.

1.4 Improving small sluices

The supremacy of mercury is about to be challenged and – with effort – may be eliminated fairly quickly.

Enter a new player, the recreational gold miners of North America, Europe and Australasia. After building their home-made sluices in accordance with the Yukon tests, many modified their sluices in an effort to recover fine gold. For years their efforts has been unpublished, yet in the public domain on internet Forums, Alaska Gold Forum <http://bb.bbboy.net/alaskagoldforum> and Mike Higbee's Prospectors Cache www.49ermike.com. Serving as endless conferences, these Forums have honed the sluice into a weapon capable of usurping mercury.

Now recreational miners - who mine for a hobby - are transferring their know-how to artisanal miners - who mine to survive. Steve and Jason Gaber ('Popandsonminers') spend under 100 USD on everyday materials such as door mats, clips, and raised expanded metal mesh to make a tuned sluice capable of recovering gold from 2mm down to 50-70μ, far better than the Yukon tests aspired to; streets ahead of most mining companies and artisanal miners.

2. Quest for the perfect tracer

2.1 Gold as tracer

But how to prove good gold recovery?

Use a tracer.

Placer gold is itself ideal as a tracer, performing well in laboratory tests [11]. But at mines introduced gold tracer is often confused with 'wild' placer gold. Irradiating placer gold to create a gold radiotracer solves this and speeds up the detection process [12], but is impractical at most mines as it demands access to a nuclear reactor and the gold radiotracer has a useful life of only a few weeks.

As an alternative, gold balls are instantly recognisable and easy to make as shown by Walsh and Rao [9]. After melting a weighed particle of native placer gold and allowing the molten bead to cool, a near-spherical gold ball is manufactured - a procedure familiar to assayers and goldsmiths. The late Karl Readle (aka MidwestDredger of Alaska Gold Forum) suggested 'rainbow' gold alloys, each ball of a distinct colour and different density as dictated by the gold:copper:silver ratio. Easy for a goldsmith to make; less easy to persuade an artisanal miner to throw into a sluice. Even then a risk exists of confusion with spherical beads of archaeological gold, seen by the writer in sluices in Kyrgyzstan and as documented by Bachmann and Tsintsov in Bulgaria [18].

2.2 Lead shot as tracer

Lead shot has been the tracer of choice of placer miners. Apart from unease about releasing toxic lead into the environment, at 11g/cm^3 lead is not quite dense enough and the densest lead-free alternatives scarcely better. Lead buckshot (6-9.1mm) is much too large, so placer miners use lead birdshot (2.03-4.83mm) as tracer yet these balls are so big a sluice can catch them easily while losing a fortune in fine gold (Fig.2).

2.3 Tungsten powder as tracer

What can be done? The search for the ideal tracer has been joined by the Alaska Gold Forum. David Bryce ('Zooka') noticed that golfers buy tungsten powder to add to their clubs to give weight, hence more momentum to drive a golf ball. With high density (19.25g/cm^3), tungsten powder is a good cheap tracer for testing gold pans and sluices. Easy to buy in golf-crazed North America or Europe but not so readily available in the Amazon jungle or Mongolian steppe.

2.4 Pen balls as tracer

Earlier this year the Alaska Gold Forum identified a near-perfect tracer – the ball of a ball-point pen. Pen balls are usually made of tungsten carbide WC, whose density of 15.7g/cm^3 is satisfyingly close to placer gold. True, pen balls often have a slightly lower density due to added ingredients and the presence of a network of pores introduced by the sintering process to engender ink flow.

That said, pen balls are consistently denser than lead shot. Much smaller too, for pen balls are commonly produced in standard sizes from 0.4 to 1.3 mm diameter. That's small enough to tune a sluice to catch much finer gold than ever possible by using lead shot as tracer (Fig.2). Pushing the limit – but still not widely available - is the novel 0.18 mm Uniball Signo Bit, with a ball small enough to write words clearly on a grain of rice.

To consistently produce smooth ink lines of a specific width, pen balls are manufactured in narrowly defined standard diameters and exhibit high polish, high sphericity and a remarkable resistance to wear. These attributes make pen balls ideal particles for gravitational experiments.



Figure 2. pen balls are smaller than lead shot
Concentrate of placer gold, with over a dozen 0.5mm pen balls of tungsten carbide spheres dwarfed by a traditional tracer of 3mm diameter "bird shot" made of lead (Pb). (photo: Robin Grayson)

2.5 Turning junk into tracers

Pen balls offer wide promise. Billions are discarded each year as junk when the ink runs dry. Now any scientist, teacher and pupil can conduct scientific tests involving settling, jumping (saltation), sliding, rolling, vibration, electrostatics and so forth of particles as dense as native gold. The particles come free of charge in waste bins in offices and classrooms across the world. Better than apples, pen balls are more spherical, tough and come in standard sizes. Sir Isaac Newton would have been pleased.

Of course pen balls suffer in being too smooth and spherical to mimic commonly flattish irregular placer gold faithfully. But pen balls do offer a cheap and rigorously standardised testing procedure for pans and sluices.

3. Outcompeting mercury

3.1 Mercury in the final clean-up

After producing a gold concentrate from their wash-plant, the placer miner upgrades the concentrate to make it saleable. For this a wide range of gravitational devices are used – clean-up sluices, small centrifuges, small jigs, elutriation towers, magnets, cones, spirals, shaking tables, helix wheels (= gold wheels) and of course a carefully used gold pan [19]. Even then, the concentrate is rarely sufficiently free of unwanted particles to be saleable and the instinct of many miners is to resort to mercury. Donor projects customarily accept this and a mantra evolved for projects to extol the virtue of retorts in achieving mercury reduction [5]. This is questionable, for while retorting slashes mercury emissions it does not eliminate mercury, and many artisanal miners shun retorts as mercury is so cheap and retorting so slow. To spread the use of retorts worldwide is probably beyond the capacity of donors, although retorts can and do achieve impressive mercury reduction locally.

From the author's observations, while the clean-up process may be quite effective at removing large particles of black sand, it is often defeated by numerous particles of fine black sand that trickle down to infill voids between large gold particles, unless fine gold already fills these spaces.

3.2 Feathers can defeat mercury

Can mercury be eliminated from the final clean-up? Indeed it can. Across Mongolia and the former Soviet Union it has already happened. The author was astounded to see, as a matter of daily routine, placer gold concentrate being cleaned using a combination of steady gentle blowing by mouth, coupled by gentle stroking with a hand-held feather (Fig.3).



Figure 3. cleaning gold by blowing and with a feather
Concentrate being cleaned by skilful use of a feather in the gold room of the Sharin Gol placer mine of Polymet Potala Ltd. Virtually all 135 placer mining companies in Mongolia use feathers, eliminating any need for mercury to clean the gold to a saleable concentrate. (photo: Robin Grayson)

Observation and inquiries show that the blow+feather technique is daily routine at virtually all the 135 placer gold companies in Mongolia at their >200 placer gold mines, producing over 10 tons a year of clean concentrate that is smelted to make ingots of dore gold for sale against assay to the Central Bank and commercial banks.

The procedure is rapid and straightforward. A table in a gold room is scrupulously cleaned and if desired is covered in a layer of greaseproof paper using paperclips. More greaseproof paper is bent and clipped to create a three-sided open top tray. Alternatively a smooth clean aluminium tray is used. Overhead illumination is very bright. Perfectly dry concentrate is added to the tray and the operator blows gently to dislodge some of the unwanted particles. A weak hand-held magnet may assist. However the most important activity is the stroking of the concentrate with the vane of a feather. There is no preference in type of bird, but the feather of necessity is quite large and commonly is a flight or tail feather. The stroking action separates the dense gold particles from the lighter particles. Experienced users tilt the feather and make use of the extreme end of the feather.

This blow-and-feather routine is ubiquitous in the gold rooms of the placer mines in Mongolia. Enquiries confirm it originated in the soviet gold mines in Siberia and plausibly may be of great antiquity. However it probably became routine following Order No.124 of 29th December 1988 by the Chief Department of Precious Metals and Diamonds of the Ministry Cabinet of the USSR that prohibited mercury in dredges, wash-plants and placer mines generally. Mongolia followed suit shortly thereafter. From that moment, all Soviet research into amalgamation technology ceased. The monthly issue of mercury by the Soviet authorities to the placer mines abruptly terminated. The blow-and-feather technique became routine.

Yet the blow-and-feather routine seems confined to the former Soviet Union and Mongolia, and seems to be unknown in the Yukon and Alaska where placer mining companies and recreational miners struggle to create a clean smeltable concentrate and resort to all manner of gravitational devices and convoluted chemical methods to achieve the same end result (Fig.4).



Figure 4. clean gold concentrate, after feathering
Clean concentrate of Mongolian placer gold, ready for smelting to make a saleable dore gold ingot. Note the many flattish gold particles that are difficult to catch, yet each year over 10 tons of gold are recovered by gravitational means and finally cleaned by blowing and using a feather. Ar Naimgan Mine of Altan Dornod Mongol.

4. Discussion

The simplicity of pen balls to test gold pans and sluices, and the ease of using a feather to clean a gold concentrate are milestones in combating mercury misuse by artisanal miners and in raising incomes. It is remarkable that the value of pen balls as tracers in gold recovery has been overlooked until now, and their potential in sedimentation experimentation has yet to be appreciated.

It is also remarkable that the use of a feather to rapidly clean a dried concentrate ready for smelting seems not to have spread outside the former Soviet Bloc.

Both pen balls and feathers are commended as examples of Best Available Techniques (BAT) for placer geologists and miners worldwide.

Diligently used, pen balls and feathers should enhance gold recovery and help to eliminate mercury misuse by placer gold miners.

But while pen balls are getting smaller, they will soon get 'left behind' as sluices improve. The quest then will be to find a tiny tracer that faithfully mimics placer gold. Tantalum metal is also being discussed as it is ductile and malleable and can be beaten into shape.

Of course gold is better, and the Already the Alaska Gold Forum wants to know how to plate real placer gold with rhodium only 0.2 μ .

5. Acknowledgements

The author is pleased to thank Michael Priester of Projekt Consult gmbH for encouragement, over 50 recreational and professional miners of the Alaska Gold Forum for valuable discussions, and over 40 mining companies in Mongolia for granting access to their placer gold operations.

Bataar Tumenbayar, Tsevel Delgertsoo, Steve Gaber, David Bryce and the late Karl Readel made valuable suggestions.

Special thanks to Jim Foley who began the Alaska Gold Forum and keeps its members focussed and friendly.

6. References

1. Grayson, Robin (1996). Key Investment Sector - Gold. Pages 33-36 in: Doing Business in Mongolia, publishers: Mongolian Business Development Agency, 155 pages.
2. Grayson, Robin; William Murray, Ursnan Tuul, Tsevel Delgertsoo and Baatar Tumenbayar (2003). Assistance to Policy Formation for Informal Gold Mining in Mongolia. Mongolian Business Development Agency, 260 pages.
3. Dore, Giovanna; Robin Grayson, Vera Songwe and Tony Whitten (2006). Mongolia - A Review of Environmental and Social Impacts in the Mining Sector. The World Bank, 41 pages. www.worldbank.org/eapenvironment
4. Veiga, Marcello M.; and R. Baker (2004). Protocols for environmental and health assessment of mercury released by artisanal and small-scale gold miners. Global Mercury Project, UNIDO, 170 pages. www.unido.org/doc/44258
5. Hinton, Jane; Marcello M. Veiga and A.T. Veiga (2003). Clean Artisanal Mining, a Utopian Approach? Journal of Cleaner Production, volume 11, pages 99-115.
6. Hylander, Lars; and M. Meili (2005). The Rise and Fall of Mercury: Converting a Resource to Refuse After 500 Years of Mining and Pollution. Critical Reviews in Environmental Science and Technology, volume 35, pages 1-36.
7. Spiegel, S.J.; and Marcello M. Veiga (2007). Global Impacts of Mercury Supply and Demand in Small-scale Gold Mining. UNEP Report, 7 pages. <http://web.uvic.ca/~gmp/documents/documents.htm>
8. Lashley, W.C. (1983). The Flatness Factor. California Mining Journal, October 1983, pages 14-15.
9. Walsh, D.E.; and P.D. Rao (1988). A Study of Factors Suspected of Influencing the Settling Velocity of Fine Gold Particles. University of Alaska, Minerals Industry Research Laboratory MIRL Report, #76, 56 pages.
10. Veiga, M.M.; R.F. Baker, S.M. Metcalf, B. Klein, G. Davis, A. Bamber and P. Singo (2006). Manual for Training Artisanal and Small-Scale Gold Miners. Global Mercury Project, UNIDO, 76 pages. <http://web.uvic.ca/~gmp/documents/documents.htm>
11. Poling, G.W.; and J.F. Hamilton (1986). Fine Gold Recovery of Selected Sluicelox Configurations. Report University of British Columbia, Northern Affairs Yukon, 77 pages. www.geology.gov.yk.ca/publications/tech/fine_gold_recovery_sluiceloxes.pdf
12. Clarkson, Randy; and O. Peer (1990). An Analysis of Sluicelox Riffle Performance. New Era Engineering Report for Klondike Placer Miners, 31 pages. www.geology.gov.yk.ca/publications
13. Clarkson, Randy (1989). Gold Losses at Klondike Placer Mines. New Era Engineering Report for Klondike Placer Miners, 44 pages. www.geology.gov.yk.ca/publications
14. Clarkson, Randy (1990). Placer Gold Recovery Research, Final Summary. New Era Engineering Report for Klondike Placer Miners, 49 pages. www.geology.gov.yk.ca/publications
15. Styles, Mike M.; J. Simpson and E.J. Steadman (2002). Good Practice in the Design and Operation of Large Sluiceloxes. UK Department for International Development, British Geological Survey BGS Report, 39 pages.
16. Zamyatin, O.V.; A.G. Lopatin, N.P. Sammikova and A.D. Chugunov (1975). The Concentration of Auriferous Sands and Conglomerates. Moscow, Nedra Press, 260 pages.
17. Wang, Weqian; and G.W. Poling (1983). Methods for recovering fine placer gold. Canadian Mining and Metallurgical Bulletin, volume 76, pages 47-56.
18. Bachman, H-G.; and T. Zdravko (2003). Placer Gold in SW-Bulgaria: Past and Present. Gold Bulletin, volume 36, pages 138-143. www.goldbulletin.org
19. Priester, Michael; Thomas Hentschel and Bernd Benthin (1993). Tools for Mining, Techniques and Processes for Small Scale Mining. GATE, Vieweg-Verlag, 537 pages. <http://sleekfreak.ath.cx:81/3wdev/CD3WD/APPRTech/G10TOE/IND EX.HTM>