Efficient nutrient management – A key component of Ecological Sanitation for the Green Olympics and long term sustainable maintenance of the Olympic Forest Park

Report on the: Technical Assistance for the development of an ecological sanitation nutrient cycling concept for the Beijing Olympic Forest Park [Part I]

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In connection with the 2008 Olympic Games an exceptionally large park, the Olympic Forest Park, is being established in the city of Beijing, China. In addition to hosting a temporary stadium during the games the park it is to be of long term multiple benefit for Beijing's habitants and tourists. It is expected to offer a space for recreational activities and to improve the micro-climate. In accordance with the Green Olympics motto the park symbolises the need to take care for a healthy sustainable environment. The plentiful vegetation, the comprehensive closed loop ecosanitary system and the lake fed with recycled water from nearby waste water treatment plants are to convey the green message to the visitors. This report reviews the current state of planning and implementation of the sanitary concept, with the aim to enable optimal use of the harnessed nutrients.

Fig. 1: Elevation map of the Olympic Forest Park

Summarising, the sanitary concept designed for the Olympic Forest Park is a feasible future orientated alternative to common one directional disposal systems. The ecosan (*Eco*logical *San*itation) technologies to be implemented offer the possibility to unburden municipal sewage treatment plants (which alternatively would process the faecal sludge), while at the same time the separately collected sanitary residues (urine, faeces and grey water) constitute an important source of plant nutrients. For the Olympic Forest Park it is a declared goal to utilise these nutrients in a sustainable way for landscape maintenance and alternatively for food or non-food crop production.

The designed concept has been critically reviewed and judged to offer the bases for an efficient nutrient cycling system. Suggestions are made on detailed and continuously updated sanitary system information, for improvement in reference to the urine or yellow water collection tanks and in respect to reassessment of the brown water or MBR treatment plant regarding layout and capacity.

While principally the planed installations for collection and treatment are comprehensive the approach for efficient reuse of the harnessed materials needs refinement. On bases of the project assessment and literature research a nutrient flow model has been build. Using the model to review the available data it became obvious that the quality and quantity of the irrigation water will have a strong impact on whether the ecosystem Olympic Forest Park is nutrient deficient or over fertilised. In the case of nutrient deficiency all ecosan manure can be recycled within the park, a surplus will demand a nutrient export. Two examples are given as an export solution: fertilisation of non-food crops in urban and of food crops in rural areas. Both options could also become a source of revenue if the nutrients are sold.

It is recommended to make firstly decisions in regard to the collection facilities and to summarise all relevant information. Then refined environmental data should be gathered and a spatial fertilisation plan, for within and if applicable outside the park, should be worked out. Consequently monitoring in respect to hygiene safety and nutrient efficiency could be implemented. Meanwhile it is suggested to provide a simple but suitable technical solution for the application of ecosan manure in the park.

Along with the implementation of technical solutions the park visitor should be offered the option to become more actively involved in the ecosan movement. An ecosan education area is suggested where the visitor can practically follow the nutrient flow from the toilet, through the collection and treatment system to the reuse for crop production. A theoretical information centre, where technologies are explained in detail and a children educational area, where they learn by playing could be additional assets.

List of abbreviation

C	-	carbon
CO2	-	carbon dioxide
ecosan manure	-	totality of human urine and faeces collected with ecosanitary systems
ha	-	hectare (100m*100m)
K	-	potassium
kg	-	kilogram
MBR	-	Membrane Bioreactor
mg	-	milligram
Mg	-	1,000 kilograms or 1 tonne
mm	-	millimetre
N	-	nitrogen
OFP	-	Olympic Forest Park
P	-	phosphorous

Content

1 State of planning and physical assessment

In the following a short overview of the environment, park layout and facilities is given, on which the qualitative description and quantitative estimation of ecosan manure flows are based.

1.1 Location and area of the Olympic Forest Park

The Olympic Forest Park lies about 10km north of the Forbidden City and covers a total area of 704ha. Though in direct connection with the Olympic Park and the area southwards of the fifth ring road where the National Stadium is located, the Olympic Forest Park is from planning and maintenance a largely independent unit. The Wuhuan Lu Express-way cuts the park into two parts (Fig. 1). The more central southern part extents over 397ha and the northern part over 307ha respectively. Deducting sealed areas, sports fields and bodies of water, in both sections slightly more than 200ha are covered by vegetation.

Primary scenic features of the park are the man made mountain (86.5m, relative to the lake water surface 48m), the main lake (total are covered by water is almost 70ha) and different assemblies of vegetation. Sports areas and playgrounds will enhance the recreational value of the park.

A temporary stadium erected within the Olympic Forest Park will host some of the Olympic Games sports events. This stadium will be dismantled after the games and the site will become additional green park area.

1.2 Visitors and staff

A total of 5.3 million visitors are expected annually. With 4.5 million visits the southern section of the park will be clearly more frequented than the northern section where 0.8 million visitors are forecasted. For the nutrient flow calculations in this report it is assumed that the visitor spends in average 3 hours in the park.

A total of 4280 staff will be employed for service and maintenance. Apart from security and few other employees no staff will reside inside the park. It is assumed for the estimation of the nutrient flows that the staff serve 250 working days per year and spend 9 hours per day in the park.

1.3 Environmental parameters

In the following the environmental parameters that influence the way and the amount of potential ecosan manure application in the Olympic Forest Park are described. As nitrogen is a nutrient of superb importance in most ecosystems and the major fertiliser derived pollutant special attention will be paid to this element. The other relevant nutrients foremost phosphorus with is strong impact onto eutrophication of water bodies need, however, to be included in future more detailed analysis.

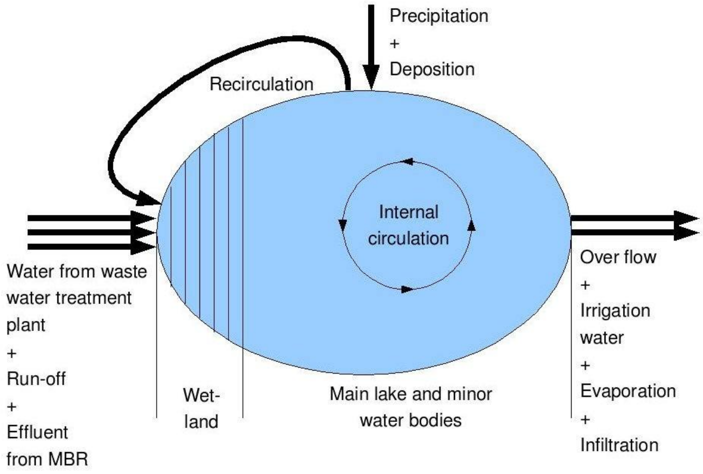

Fig. 2: Principal flows of water and nutrient in the lake system of the Olympic Forest Park

1.3.1 Climate

Precipitation in the Beijing area is concentrated during the warm summer months from June to August. During this period in average about two thirds of the total annual precipitation of 619mm is recorded. A comprehensive study on the inter-annual variation of annual precipitation shows that abnormalities in the range of about ±20% of the long term annual average rainfall are frequently recorded (compare Johnson, Koenig, & Kopp, 2003). Further a negative correlation between the build up area and the annual precipitation has been discovered (Zhang et al. 2007).

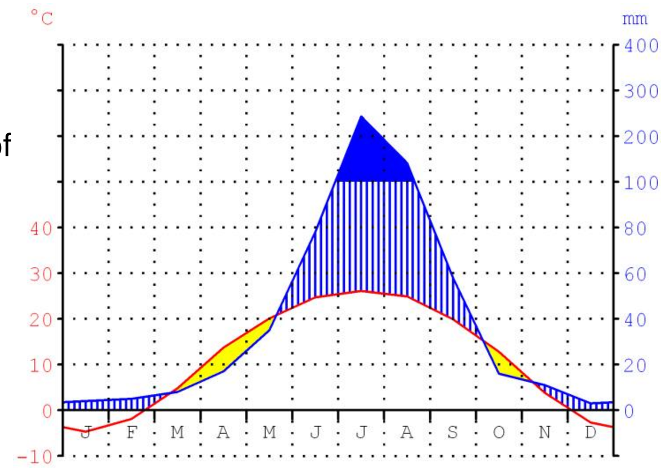

Fig. 3: Climate diagram of Beijing (52m)

1.3.2 Soil properties

The original soil type in most of Beijing's urban area is Calcaric Cambisol, a loam/sandy loam (Yu et al., 2006). Generally the soils on the North China Plain have a high infiltration rate and are prone to significant nitrogen leaching. This characteristic in combination with high nitrogen fertilisation has led to sever nitrate pollution of the groundwater aquifer (Tang, 2004; Liu, Wu, & Zhang, 2005).

Due to major land surface shaping works carried out before and during the park establishment a large number of samples are needed to describe properly the physical and chemical properties of the soil. A preliminary work plan to access the initial soil conditions and monitor them throughout a prolonged period, thus to study the impact of application of ecosan manure onto soil fertility has been prepared (by Chunjiao Li, employee of Urban Planning Design Institute of Tsinghua University).

Such investigation will also provide important information on the long term soil nutrient accumulation. Presently only data form comparable situations can be used as an indication. A long term experiment conducted in Germany at two different site compared the changes of total nitrogen in the soil under conventional farmland and commercial forests. Independent of location and the land use form an accumulation of about 10.0Mg C ha-1 along with 1.6 to 2.8Mg N ha-1 was observed within 27 years (Rinklebe & Makeschin, 2003). Under certain circumstances, however, nitrogen accumulation can be slower and prolonged as research on abandoned agricultural land has shown (Knops & Tilman, 2000). For the OFP a linear accumulation of 3Mg N ha-1 over 50 years is assumed.

Depending on the soil, land use, nutrition management, precipitation and irrigation the amount of nutrients lost from an ecosystem over the time can vary strongly. For the current nutrient flow balance a stable annual nitrogen loss rate of 30kg ha-1 through leaching and run-off is assumed. This value is comparable to natural and managed forests (Cole, 1995; Rothstein, 2005), but depends naturally strongly on the actual nitrogen input.

Phosphorus is lost from ecosystems through run off, but the amounts are comparably low from well managed perennial systems. Considering the heavy precipitation events in Beijing during the summer a annual run-off loss of 1.5kg P ha-1 can be assumed (Johnson et al., 2003).

1.3.3 Deposition

Atmospheric deposition of nitrogen occurs primarily via precipitation. The total (wet + dry) deposition measured in agroecosystems of Beijing and other urban areas of China is about 31kg N ha-1 (Chen & Mulder, 2007; Liu et al., 2006). Sulphur deposition at over 100kg ha-1 (Wang et al., 2003) is another important atmospheric influx. Phosphorus deposition is in contrary to nitrogen for non-aquatic ecosystems usually of lower significance and under local conditions roughly 1kg ha-1 per year (Luo et al., 2007). In temperate forest ecosystems deposition of potassium is usually of minor importance (Lynch, Horner, Grimm, & Carrick, 2006), but research showed that potassium influx trough desert dust (Guinot et al., 2006; Zhang et al., 2003) and through ocean or sea spray (Arianoutsou, 1989) can reach significant levels.

Atmospheric deposition has been recognised as having a significant impact on plant development and should therefore be integrated into fertiliser strategies (Hatch, Goulding,

& Murphy, 2002).

1.3.4 Lake water quality

The lake water quality is relevant to the ecosanitary nutrient cycling concept as it is intended to use the water for irrigation in the park. Precipitation and effluent from nearby sewage treatment plants, the Beixiaohe plant easterly and Qinghe plant northerly of Olympic Forest Park, will feed the lake. Additionally some water form the planned MBR in the park and during the rainy season also run-off water will enter the lake passing through planted wet lands (about 8ha).

Two outflows, the diversion of the Qing River and the Yangsha Grand Ditch, allow discharge after heavy precipitation events. Next to irrigation water will leave the lake through evaporation and infiltration.

Due to the proportion of the lake to the land surface to be irrigated and the relatively low precipitation it is likely that the greatest part of the water will have to be provided by the sewage treatment plants. Therefore the nutrient content of the lake water might be within the magnitude of the effluent from treatment plants.

The national limit for treated waste water discharge in natural lakes N is 5.0 mg l^{-1}, P 0.5 mg l^{-1} and for artificial impoundments or lakes 15mg N l-1 (GB/T18920-2002). Both limits are well above national surface water quality standard class V of 2.0 mg N l-1 (GB 3838-2002) and would classify the lake with no other significant inflow as hypertrophic (Shuncai & Chen, 2000) . The actual nitrogen load of surface waters in Beijing is, however, often even much higher and reaches in some cases up to 120mg N l^{-1} (Fang, Xue, & Yong, 2004).

Actual data of the lake water quality are not available as the lake is not yet filled, but the effluent from the Beixiaohe sewage treatment plant has an average load of 33mg N l-1. This value is used as a maximum value in the nutrient flow calculations.

Previously a joint Sino-German team suggested methods for advanced treatment for the water used in the OFP (Ernst et al., 2007). At this moment of time an expert group is working locally on the issue, but the final concept is not yet available.

Pic. 1: Constructed wetlands in the Olympic Forest Park

1.3.4.1 Irrigation

A study on most economical irrigation amounts for turf grasses with different degrees of drought resistance in Beijing shows that irrigation levels of about 350mm per year are needed (Zhang et al., 2007). Levels in this magnitude are also confirmed by agricultural research in the region (Yu et al., 2006). Few sources suggest significantly higher irrigation volumes (Ernst et al., 2007). For the preliminary calculations in chapter 1.7 350 and 500mm are used as park average irrigation levels, where the higher figure takes the high precipitation variability between the year into account. It must kept, however, in mind that the actual demand varies strongly between the communities and might much higher for e.g. flower beds and lower for tree stands.

At 5 mg N l-1 (in accordance with GB/T18920-2002) and on 33.0 mg N l^{-1} (value actually measured) irrigation could therefore annually supply from 17.5 to 165.5kg N ha-1.

1.3.5 Park vegetation

The landscape designers have categorised the vegetation into two classes: dense forest covering 340ha and open forest extending over about 60ha. The dense forest area is

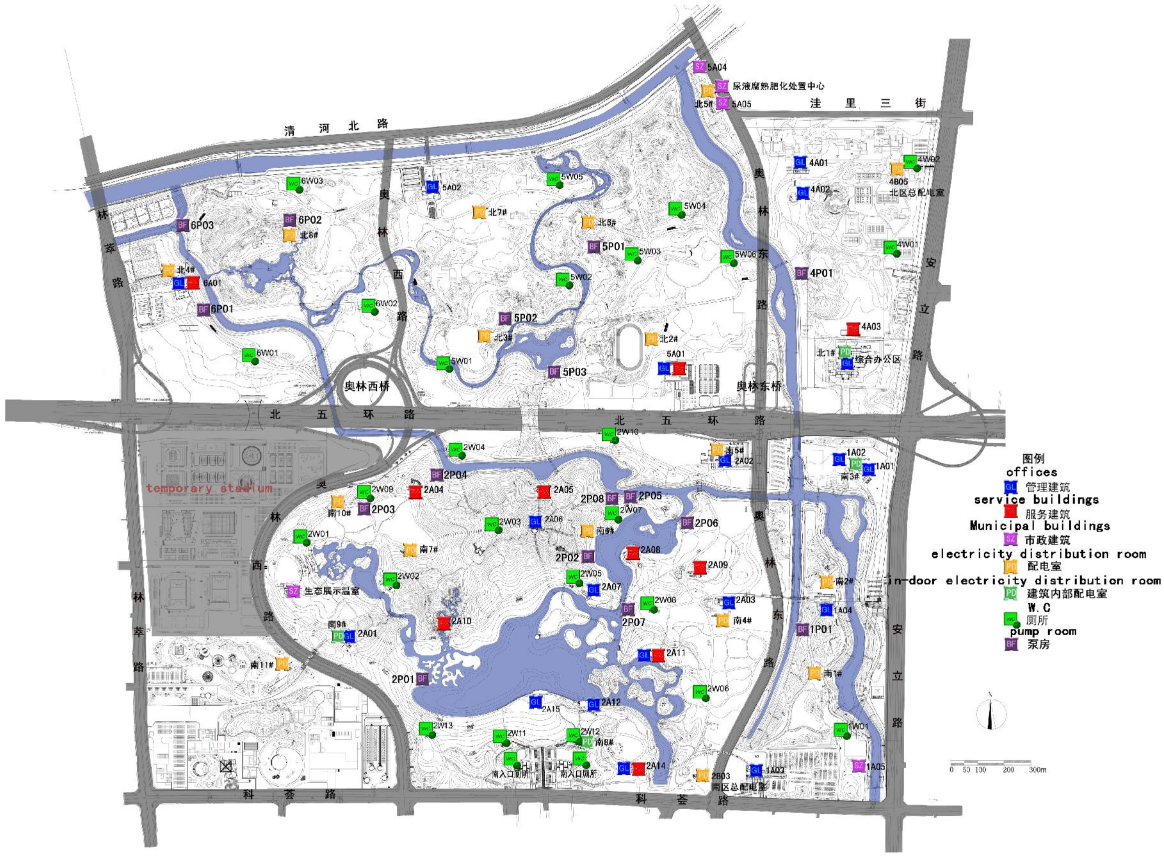

Fig. 4: Location of the sanitary blocks in the Olympic Forest Park

covered with coniferous and deciduous trees in the ratio 6 to 4, while the open forest area includes lawns, shrub/bush vegetation and flower assemblies. Over 90 plant species have been short-listed for planting in the park (see appendix). Though some fruit trees (e.g. mulberry, walnut) are included, there is no significant food or non-food crop production planned to take place in the park.

Less than 10% of the species belong to the Fabaceae family that is known to profit from a tight symbiosis with (atmospheric)nitrogen-fixing bacteria. Non-symbiotic nitrogen fixation which occurs in canopies, ground litter layer as well as soil rarely exceeds 2kg ha-1 per year. Both fixation paths result in a net-nitrogen input probably not exceeding 7kg ha-1 per year in average of the total park area.

On the other hand nitrogen is lost from ecosystems through volatilisation especially after application of fertilisers, urine and manure. The amount of nitrogen that leaves an ecosystem depends on multiple factors including the way fertiliser or manure is applied (Whitehead, 1990). It is here assumed that both biological fixation and volatilisation neutralise each other in respect the ecosystems balance.

1.3.5.1 Biomass

In Fig. 5 an assumed sigmoid function is fitted for the development above and below ground biomass as an average for the whole green park area (excluding sports grounds) over a 50 year horizon. The annual litter production plotted blow includes leaf shedding, grass cuttings and all trimming and logging.

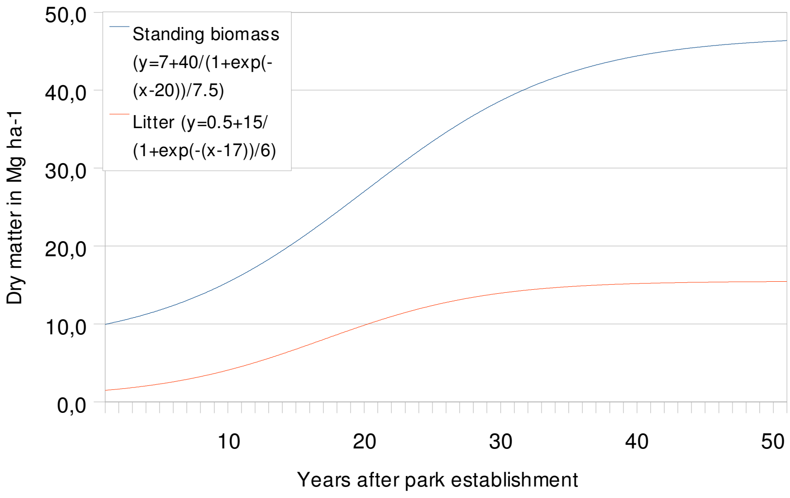

Fig. 5: Development of total above and below ground standing biomass and annual litter production

On bases of the dry matter composition the function can be used to calculate the OFP biomass nutrient content nutrient at any given time. Assuming an average biomass dry matter nutrient content of 1.75% N, 0.12% P and 0.70% K (Elliott, 2002; Johnson, Henderson, & Todd, 1988) the OFP biomass will contain in 50 years after park establishment 811kg N ha-1, 56kg P ha-1 and 325kg K ha-1 and the litter turn over will be

270kg N ha-1, 19kg P ha-1 and 108kg K ha-1 per year.

1.4 The sanitary concept for the Olympic Forest Park

An ecological sanitary concept has been chosen for the OFP with the goal to recycle the nutrients that are contained urine, faeces and organic matter, while maintaining high environmental and hygienic standards. Human excreta posses a minimal load of pollutants such as heavy metals if compared with common waste water that includes loads from industrial areas and roads. Also in comparison with some commercial fertilisers human urine has an outstanding low heavy metal load (Jönsson et al., 1997).

Pathogens that might occur in the excreta can be deactivated by appropriate technologies, such as storage and composting. Thus, properly treated human excreta are a suitable nutrient source if healthy food is to be produced. Apart from the important recovery of nutrients the system relieves the local waste water treatment plant from additional loads and reduces the freshwater and energy demand. This type of source intervention has been recognised as one of the important steps towards water pollution control in the country (Qian, Wen, & Huang, 2007).

The primary functional units of the concept are the sanitary facilities, the installations for collection, equipment and infrastructure for transport, the treatment and storage facilities and the tools for application.

1.4.1 Sanitary blocks

Throughout the park 27 public sanitary blocks are positioned in such a way that the nearest toilet is easily reached from any point in the park. Currently the blocks are under construction, most of them in shell form without any sanitary installations fitted. The blocks are being erected and equipped by different contractors, who use materials of numerous suppliers. In several cases the exact type of fitting or installation is not yet finally decided.

The current state of planning foresees that 5 of the sanitary blocks will be equipped with dry separating toilets that collect the faeces in containers below the toilet/squatting pan. For the purpose of hygienisation and odour reduction the faecle matter is enriched with saw dust and stirred mechanically.

The other 22 blocks are equipped with flush separating toilets/squatting pans by different contractors, of these the average flush volume for the faeces is 6l and for urine 0.6l. Thus, the flush water volume fulfil the national requirements in respect to water consumption (compare 3.1). The urinals in all men's restrooms are waterless.

It is planned to equip all sanitary block with tanks that collect the sources separated material flows. Source separated the urine/yellow water is collected in underground tanks of about 15m³ each. The faecal matter is flushed in to a three chamber septic tank systems with an mean volume of 75m³ (50-100m³). For the sake of simplicity the same usage level is assumed here for all sanitary blocks.

The sanitary facilities for the staff are equipped with common sanitary systems. The waste or black water is collected in a central three chamber septic tank.

1.5 Transport and treatment facilities

Vacuum trucks of 4m³ capacity are planned for the transport of brown and yellow water from the public sanitary blocks as well as for the black water from the staff's facilities. The trucks will deliver all materials to a central treatment plant, that consists of a yellow water storage facility, a MBR waste water treatment plant and a composting plant.

Pic. 2: Vacuum trucks delivering waste water to a MBR waste water treatment plant in Beijing

The urine is to be stored in several underground tanks of 40-50m³ each with a total volume of 2,000m³. With a potential storage time of at least 180 days it is expected to deactivate pathogens sufficiently.

Brown and black water undergoes a liquid/solid separation. The effluent from the separator passes through a biological membrane reactor before it enters the lack through the constructed wetlands. The exact type and specifications of the installation is not yet decided. Currently the layout foresees to treat only waste water generated within the park with a daily maximal treatment capacity of 60m³, with a total nitrogen content in the effluent of less than 15mg l-1 (pers. com. He). The nitrogen removal efficiency is comparable to what is achieved elsewhere in Beijing (Liu, et al., 2007).

The current state of planning collects and treats grey water together with brown water. At 0.5l per hand wash this implies almost 3,000m³ per year would have to be treated additionally. In accordance with the recommendation to dispose grey water separately in local infiltration beds (chapter 6.3) and due to the low nutrient content, grey water is not further included in this preliminary estimation.

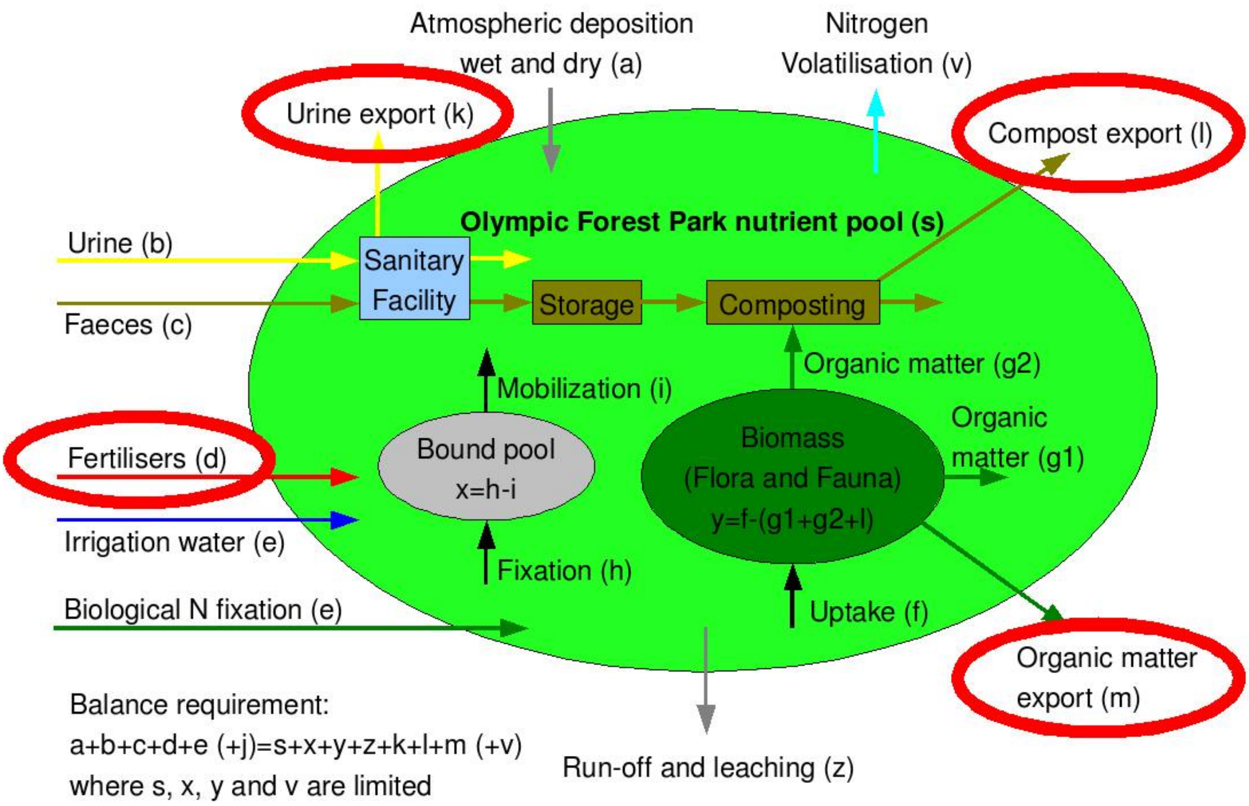

Fig. 6: Simplified nutrient flow model for the green areas of the Olympic Forest Park (includes soil and biomass)

A compost plant with an annual treatment capacity of about 2,000Mg of fresh organic matter is under construction. Apart for grass clippings, leaves and other biomass from the park maintenance, it is planned to co-compost the faecal matter from the dry toilets as well as all solid material from the liquid/solid separation plant.

1.6 Ecosan manures and black water – volume and nutrient content

Relevant nutrient sources from the ecosanitary installations in the Olympic Forest Park are human urine or yellow water, faeces or brown water and faecal matter from the dry toilets. The respective volumes and nutrient contents are listed below, where a visitor sex ratio of 1:1 is assumed.

1.6.1 Urine plus flush water – Yellow water

Human urine differs in its chemical properties strongly between individuals and reflects

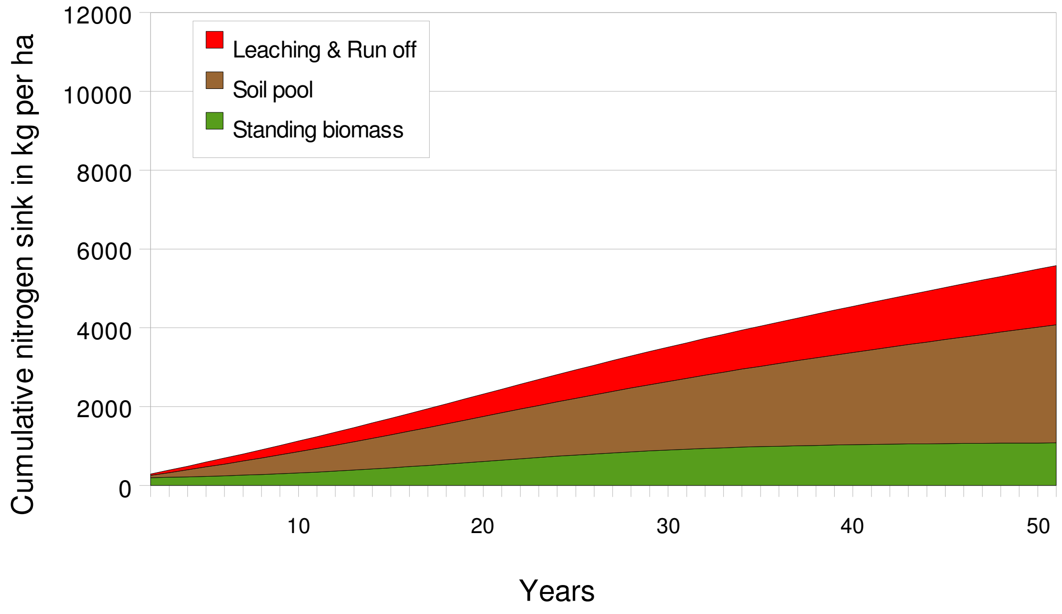

Fig. 7: Cumulative nitrogen sink in the Olympic Forest Park

primarily the personal alimentary habits. A summary of a large number of medical investigations suggests following population averaged nutrient contents: 7.1g l-1 N, 0.7g l-1 P and 1.9g l-1 K (Germer, 2007). Amounts based on area specific data confirm this magnitude. The integration of annual nutrient excretion rates for China (Jönsson & Vinneras, 2004) with the average urine volume of 1.6l (Gao, Shen, & Zheng, 2002) suggest 6.0g l-1 N, 0.7g l-1 P and 2.2g l-1 K. In view of the assumed higher nutrient intake of the park visitors in comparison with the average chines population, for the present calculations 6.5g l-1 N, 0.7g l-1 P and 2.0g l-1 K are used. The nutrient flow calculations assume that the average visitor excretes in average 17.5% of the daily urine during their stay in the park (the figure takes into calculation a 3 hour stay and that a disproportional large amount of urine leaves the body in the morning). Further it is taken into calculation that men use the dry urinals and urinate in sitting toilets or pans only when they defecate. A collection efficiency of 90% and a volatilisation loss during collection and storage of 10% nitrogen is assumed. The assumed key figures suggest that about 1,100m^3 of human urine or 2,400m^3 yellow water can be harnessed annually for nutrient recycling.

The nutrient content of the flush water is in comparison with the one of urine very low and neglected here. Thus, yellow water provides 6.4Mg nitrogen, 0.8Mg phosphorus and 2.2Mg of potassium per year.

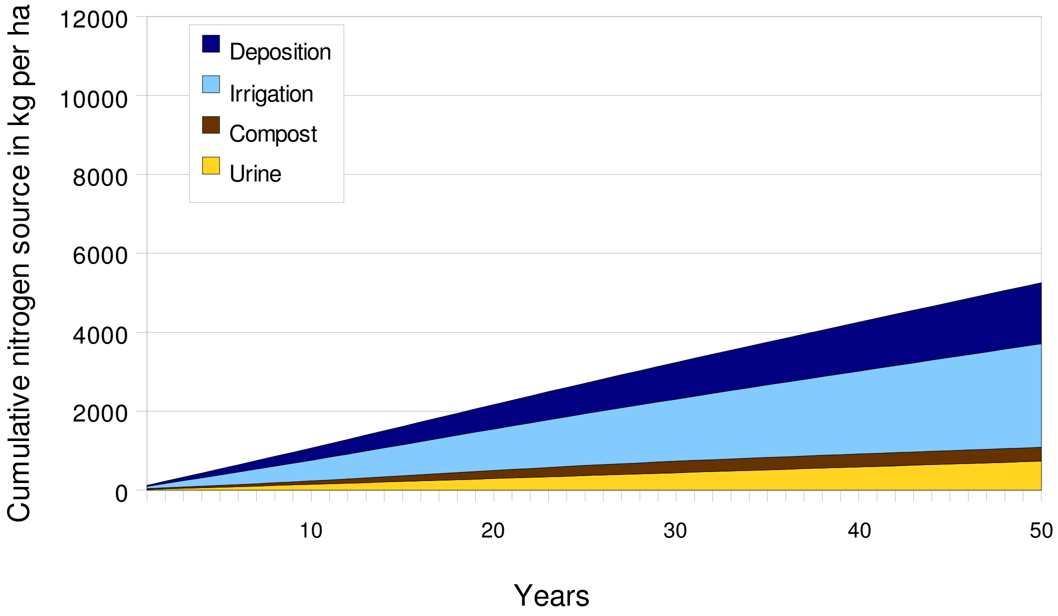

Fig. 8: Accumulative nutrient inflow into the Olympic Forest Park under 350mm irrigation per year and 15 mg N l-1 in the irrigation water

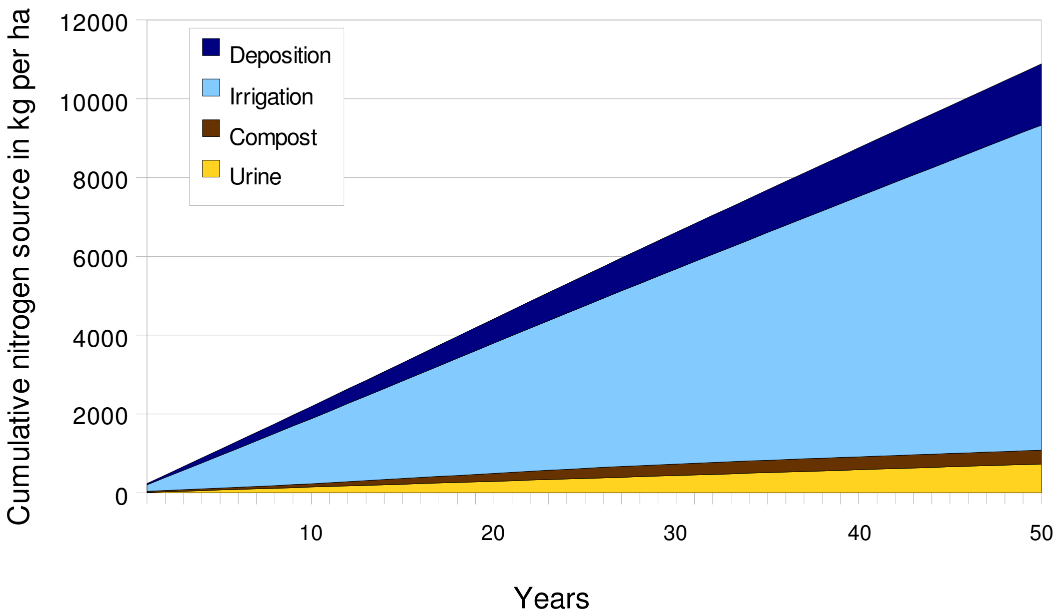

Fig. 9: Accumulative nutrient inflow into the Olympic Forest Park under 500mm irrigation per year and 33 mg N l-1 in the irrigation water

1.6.2 Faeces plus flush water - Brown water

Average daily faeces excretion is about 150g and the fresh matter consist to 75% of water. The dry matter contains 18.0g kg-1 nitrogen, 4.0g kg-1 phosphorus and 3.6g kg-1 potassium (Germer, 2007). It is assumed that the visitors excrete during their stay in the park 15% of the total daily faeces. According to these data the flush toilet facilities are expected to harness per year 3,900m³ brown water and provide 0.4Mg nitrogen, 0.1Mg phosphorus and 0.1Mg of potassium per year. Volatilisation losses are neglected for the time being.

1.6.3 Faecal matter – faeces plus saw dust

The remaining 19% of the faeces not considered in the above chapter is collected in dry toilet systems. Humidity in the collection tank of this system is partly absorbed saw dust and partly evaporated. It is assumed that during storage 25% of the moisture is evaporated and 30% of nitrogen is emitted in ammonia form through volatilisation. The basis for this assumption is similarity of latrines to open storage of animal manure. The resulting annual bulk of 16Mg faecal mass contains 96kg nitrogen, 21kg phosphorus and 19kg potassium.

1.6.4 Black water

Black water originates only from the staff facilities. For an estimation the staff force is assumed to excrete one third of urine and faeces within the park perimeters. Further 40l average daily water consumption for flushing and personal hygiene is taken into calculation. Based on these assumptions 2,000m³ black water containing 170kg N, 29kg P and 55kg K can be expected per year.

1.7 The Olympic Forest Park nutrient flow model

In accordance with the theme 'Green Olympics' and the wish to run the Olympic Forest Park environmentally sound and sustainable the intended fertilisation scheme with ecosan manure must be optimised in such a way that the park vegetation is sufficiently supplied with all nutrients necessary for vigorous growth, while environmental pollution through over fertilisation is avoided. A nutrient flow model that integrates mass flows and the soil nutrient status can indicate the optimal application rate of fertilisers or ecosan manures. From these application rates decisions can be taken on the ideal area, method and tools for fertilisation.

A simplified nutrient flow model has been developed for the Olympic Forest Park (Fig. 6). The numerical base for the model is a spread sheet table that allows to modify certain parameters in order to forecast implications on the nutrient balance. The model highlights the management possibilities to modify the nutrient balance of the park by regulation input and output. On the input side the use of fertilisers and measures that change the quality of the irrigation water could actively alter the import of nutrients into the system. On the output side the management can influence the nutrient balance of the system by exporting nutrients contained in urine, compost and organic matter.

All data needed to calculate a nutrient balance are mentioned in the above chapters. As simplification the nutrients contained in brown and black water are allocated in full to the compost.

1.7.1 The nutrient balance scenarios

Actual nutrient balances for ecosystems are very complex and often the underlying processes are not yet fully understood. Here a strongly simplified nitrogen balance is used to demonstrate the potential discrepancy between the size of sink and source. The long term effect is integrated by observing a 50 years period. In Fig. 7 the sink as a sum of losses through leaching and run-off plus accumulation the soil as well as above and below ground biomass is plotted.

Of all above assumptions the amount and the quality of the irrigation water has the strongest impact on the nutrient balance, which is graphically demonstrated in the two scenarios. In the first scenario a low irrigation water nitrogen content of 15mg l-1 (see 3.1 and compare Ernst et al., 2007) and an irrigation scheme of 350mm per year is assumed. In this case (Fig. 8) all yellow water, compost and organic matter could be used within the park, without upsetting the balance between source and sink. This would require consequently an appropriate application system.

The second scenario assumes an irrigation water nitrogen content of 33mg l-1 and an irrigation scheme of 500mm per year. Under this assumption (Fig. 9) all necessary nitrogen for vigorous growth of the vegetation would be supplied by the irrigation water, deposition and biological fixation. Thus, theoretically the ecosan manure could be exported in it's totality. As the different vegetation assemblies have specific nutrient demands it is, however, likely that certain areas will despite the nutrient influx through irrigation remain nutrient deficient. Therefore a spatial concept together with a detailed nutrient flow model that includes nutrient export options is needed.

The surplus of 5Mg ha-1, in the high N input scenario, during the 50 year time frame (Fig. 9) or 100kg ha-1 annually is is in comparison with commercial N fertilisation rates in the region of up to over 600kg ha-1 in one year low (Liu et al., 2005). Not only from the ecological, but also from the economic point of view it is, however, interesting to use the surpluses N as efficiently as possible. Two options for urine and compost export into productive agricultural and forest systems are described in chapter 6.7.

2 Potential national ecosan and agricultural research partners

For the monitoring and trial work on the nutrient flows:

- Prof. Dr. Shu Xiang Zhang of the Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences

The institute of Prof. Zhang is equipped with all necessary facilities and has staff available to cooperate in developing and implementing work on the Olympic Forest Park immediately. A further advantage is the experience from previous and current cooperation with German institutions (e.g. CIM, Gtz).

Regarding the validation of the hygiene standards:

- Prof. Dr. Li Zifu of the Department of Environmental Engineering, University of Science and Technology Beijing.

Beyond extensive experience in respect of hygienic safety of alternative waste water treatment Prof. Zifu has profound knowledge of knowledge in reed-bed vertical flow filters (see also 6.3). [As a direct outcome of the meetings held and suggestions presented Mr. He of the Zhongyuan company approached Dr. Zifu in order to support hygiene monitoring of urine collection and application.]

3 Regulative framework

On international level the WHO has issued 'Guidelines for the safe use of wastewater, excreta and greywater' that cover all health related aspects of ecosan manure use. The requirements on the ecosan manures in respect the pathogen load reduction are the same for public park as for the cultivation of vegetables eaten raw, thus the most stringent once that apply. Recommendations are given in detail for waste water, which account also for urine and grey water (E.coli 10^3 in 100ml, Helminth eggs 1 per g of total solids per l). For faecal matter or sludge pathogen enrichment of the soil should not be beyond comparable waste water irrigation.

IFOAM is the international organization for organic farming movements. The IFOAM norms state that in organic farming the use of human excreta is prohibited on crops for human consumption. However, exceptions may be made according to the same norms and an annex to the norms states that source-diverted human excreta may be used if it is monitored to avoid contamination, and not directly applied on edible parts of crops (Kvarnström et al., 2006).

3.1 National regulations

A detailed report on all regulative standards and norms on in-house sanitary installations is currently prepared by local partners with the support of BORDA e.V. (pers. com. Mang).

A selection of regulations with practical implication for ecosan manure application are listed below:

GB 6952-2005 – The National Standard for Sanitary Wares sets maximal flush volumes for new toilet facilities. Maximal volumes are 6 litres per flush for sitting toilets and 8 litres per flush for squatting pans.

GB 3838-2002 - The surface water quality standard classifies surface water into 5 quality categories - e.g. Kjeldahl Nitrogen in mg l-1: I-II 0.5, III 1.0, IV 1.5, V 2.0. Class V is mainly applicable to water bodies for agricultural use and landscape requirement.

GB 18918-2002 - Standard for Pollutant Discharge of Sewage Treatment Plants in Cities and Towns. Grade I Standard A and B limit total nitrogen in effluent from waste water treatment plants to 15 and 20 mg l-1 respectively.
GB/T18920-2002 - Quality standard of reused water as landscape water body. Regulates e.g. the total nitrogen level at <15mg l-1 for scenic impoundments and lakes.

4 Nutrient and mass flow management in public parks

In non of the parks visited (Chao Yang Park, Summer Palace, Botanical Gardens and Yuan Da Du Park) an ecosanitary system is implemented. The toilet facilities usually have tanks from where vacuum trucks remove the material regularly. Experts form national parks expressed, however, the urgent need for alternative sanitary concepts for parks such as Jiuzhaigou National Park and water sheds like Mountain-River-Lake area in the Jiangxi Province.

In larger inner city parks there are composting sites where grass clippings, leaves etc. are treated. The compost is used along with commercial fertilisers as a nutrient source for the vegetation in the parks, but according to the manager of Chao Yang Park the actual input of fertilisers is low due to continuous financial restrain. Therefore, it seems possible to maintain exemplary ornamental vegetation almost exclusively by nutrient input from deposition, irrigation and compost recycling. Moreover, in smaller parks like the Yuan Da Du Parks organic debris is even not composted and recycled. According to staff the organic matter is disposed through the municipal refuse service.

5 Nutrient cycling in other ecosan projects

The clear priority of the ecosan related projects visited (biogas at De Qing Yuan Chicken Farm and dry fermentation at Chuang Xin Dairy Farm) is to generate electricity, to unburden the respective waste water treatment plant or to comply with environmental standards. Also for biogas installations in Beijing nutrient recycling is if at all a positive side effect. One domestic sludge treatment facility removed and composted solids from the waste water. According to the manager the dried compost is enriched with nutrients and sold as organic fertiliser.

In general the reuse of nutrients from night soil, which has kept Chinas agriculture productive over millennia, continuous to decrease, while the use of chemical fertilisers is further growing. The Ministry of Agriculture, in response, has begun to promote the use of organic fertilizers by it's green food and other campaigns.

A studied blueprint from a large ecosan project (Erdos Eco-Town Project) under development in the Dongsheng County suggests that there nutrient recovery for agriculture is one of the declared goals.

6 Suggestion for optimised material management

6.1 Sanitary installations

Collection and treatment facilities can be best optimised in functionality and size if exact knowledge of the sanitary layout is available. Limits and guidelines given to the respective contractors are not sufficient. Therefore, an assessment sheet (Appendix 1) has been developed that shall be used to gather exact information for all sanitary block in the Olympic Forest Park.

Where no decision on the installation type has been taken, it is generally best, to use solutions with a minimised water demand and that keep urine and faeces as concentrated as possible. Dilution increases transport costs of the collected material in relation to the contained nutrients.

6.2 Yellow water collection tanks

The current state of planning furnishes all sanitary block with 15m³ single chamber yellow water collection tanks. Prolongation of the hygienisation time could be achieved by splitting these tanks into two separate chambers of the same storage volume. The additional storage time for one chamber would be equal to the time needed to fill other chamber and can be estimated to be roughly 30 days (yellow water production 2,500m³ per year, 27 sanitary block, storage of two times 7.5m³ = 15m³).

Ideally the size of each chamber would be matched exactly with the multiple capacity of the transport mobile to minimise transportation expenditure. Thus with the planned transport mobile capacity of 4m³ each chamber should have a volume of e.g. 8m³.

Alternatively to a prolonged sanitation time the extra storage could be used to reduce the storage capacity and cost of the central treatment plant.

Due to the large volumes and the very high buffer capacity of urine, acidification to avoid ammonia emissions and odour is not economical (Udert, Larsen, & Gujer, 2006). The actual ammonia loss is usually low and odour harassment can be avoided if the material is transported when no visitors are in the park (e.g. early morning, night time).

6.3 Brown and black water collection and treatment

The brown water that has to be treated, in favour to lower the pathogen load and to make the material easier to handle, would almost double if the grey water was added. Due to this reason local planted infiltration beds at each sanitary block are recommended here for the disposal grey and cleaning water.

The planned treatment of brown and black is at the current state of information not comprehensible, if the ecological and economical sensible separate grey water collection is assumed. Questions regarding installations, treatment capacity, material disposal and economic feasibility remain open:

- The dimensions of the brown water tanks (50-100m³ per sanitary block, 22 block total 1.650m³ is about half of annual brown water production of <4.000m³) seem to be oversized and with a three chamber system to complex, if the brown water is to be treated as proposed (solid/liquid separation and MBR).
- The treatment capacity of the proposed plant is at 60m³ per day about double as high as the expected production of brown plus black water.
- Disposal of the effluent form the treatment plant into the lake, also if through the wet lands, should be in any case avoided (pointed out by Mr. Kraft during joint visit of the park).
- Due to the small capacity and low utilisation the cost per treated cubic meter will probably be exceedingly high if compared with alternative technologies.

It is suggested to review the decision tree and compare the MBR option with vertical flow reed-beds or alternatively with the treatment in biogas digestors.

Reed-beds are known to be a viable solution for the treatment of black water. The passage of waste water through a multiple septic tank system reduces the content of solids and organic matter and would function as a pretreatment. Due to the significantly lower nutrient content in the brown water by the urine separation it is expected that reed-beds will have a long operational life time.

For the biogas treatment a high content of easily digestible carbon is necessary. Therefore this option would make the large three chamber septic tank systems dispensable. For the same reason the separated collection and treatment of grey water would be of advantage. Both systems can be set up decentralised in each park sections and would reduce necessary transport drastically.

6.4 Establishment of an upgradable application system

The nutrient content of yellow water, which is low in comparison with commercial fertilisers, demand the application of large volumes if a significant nutrient input is to be realised. To supply for example 50kg N ha-1 at a yellow water nitrogen content of 6.5g l-1 a total of almost $8m^3$ are required. Therefore simple manual application as commonly done with commercial fertilisers is not a feasible option. Fertigation directly onto green leaf area e.g. lawns requires even higher volumes due to the necessary urine dilution in order to avoid burns.

Further, the actual nutrient flows that will prevail in the Olympic Forest Park can only be estimated with a limited degree of certainty. Both, the fact that not all decisions are taken in respect to the technical installations that are going to be used as well as the lack of comparable projects contribute make the forecast difficult.

Therefore, for the Olympic Forest Park three solutions suggested, where trucks or mobile application units are the first, which should be implemented in any case. The other two are of a higher degree of mechanisation and posses more fixed installations. These solutions could be implemented after the games, when necessary and sufficient knowledge on the actual nutrient supply and demand is available.

6.4.1 Mobile application unit

Pic. 3: Truck used for irrigation in the Beijing Botanical Garden

Small trucks similar to the ones used for watering city greens and park areas in Beijing (Pic. 3) would allow application with a very high degree of flexibility throughout the whole park area. Equipped with long pressurised hoses sensitive areas (e.g. flower beds) and places difficult to access could be easily reached. Ideally the vacuum trucks planned to transport the urine from the sanitary blocks to the central storage/treatment plant would be fitted with the necessary pumps and hoses. Robust in construction and with functional parts accessible for maintenance such mobile units could allow the application of both, pure and diluted urine or yellow water. Calcium and magnesium phosphates as well as other sediments are unlikely to cause any blockage and thus these nutrients would be efficiently recycled too.

6.4.2 Fixed pipe-hose system

Used in several parks in Beijing (Pic. 4) this system is based on underground pipes that have several outlets/taps where a hoses for irrigation are attachable. Actual application is equal to the above describe mobile units. Apart from the pipes to be installed this system requires further decentral storage tanks and pumps. When regularly flushed with pure water this system is suitable for application of urine in all levels of dilution.

Pic. 4: Watering of lawns and trees with a hose

6.4.3 Fixed drip or sprinkler systems

Due to the limited watering radius of drip emitter and sprinklers these systems require the highest degree of fixed installations (esp. pipes). Otherwise decentralised tanks and pumps (though with a higher capacity) are needed as for the fixed pipe-hose system. Advantages over the two previous methods are the very limited labour demand and the fact that this method of application can easily be used at any day time. It is thus an interesting option when night time application is desired in favour to limit nitrogen volatilisation and odour harassment.

6.5 Ecosan educational area

As an awareness rising measure the establishment of an ecosan educational area is suggested. The vision is to establish a condensed touch and see area that transmits comprehensively the ecosan concept (see Pic. 5). Around one or two sanitary blocks (flush + dry system) exemplary small scale collection, treatment (including storage and composting

Pic. 5: Unfertilised(left) in direct comparison human urine fertilised maize (right) demonstrating the potential of ecosan in Ghana

facilities) as well as the agricultural use and resulting advantage could be demonstrated. For a better understanding crops grown should be well known food plants like cabbage, onions, maize and apple trees so that the visitor can follow the cycle and consequently understand the importance of ecosan.

The establishment of such educational areas would transmit the ecosanitary message also in the case if the bulk of ecosan manure is exported into other ecosystems (compare chapter 6.7). A special area for children would be advantageous too. In a promoter/teacher assisted nursery children could by playing increase their awareness to water pollution and resources constraints and learn how ecosan contributes to improve agricultural production, human health and the standard of living.

An information centre, where ecosan technologies from the OFP and comparable projects around the world are exposed and described could be an additional asset, especially for the involved companies.

6.6 Nutrient flow model

The preparation of an advanced nutrient flow model that can continuously be optimised by additional data is suggested. It should be spatial in respect to integrating areas of specific nutrient demand within and outside the park. The actual nutrient demand should be defined not only by the productivity of a certain ecosystem, but be optimised in respect to the overall benefit per nutrient unit. For the forest areas in the Olympic Forest Park high productivity is for example from a certain stage of growth of no further advantage and the areas could be maintained without additional nutrient input (compare chapter 4). Therefore it might be advisable to use the available esosan manure after full forest establishment in areas where they generate revenue or constitute a higher ecological gain.

The nutrient flow model should ultimately be used to decide where how much ecosan manure will be best applied.

6.7 Off site ecosan manure use

The use of ecosan manure harnessed within the Olympic Forest Park partly beyond its borders could offer following advantages: a) increment of the nutrient efficiency (e.g. reduction leaching losses), b) if used for food production a comprehensive close nutrient cycle would be established, c) if used for food crops that are not consumed raw or for non-food products less stringent hygiene regulations apply. Sinks outside the OFP could also be used as a back-up system in case pathogen limits can not be met. Two options which could be implemented together or singular are described below.

6.7.1 Ecosan manure fertilisation of express-way green strips

A national regulation demands that green strips are established alongside new high- and express-ways. Depending on the local situation these strips are to be 20m wide. Instead of having trees on the strips just for the beautification purpose the commonly planted poplar trees could be use commercially for pulp or as renewable energy. Depending on how intensely poplar plantation are managed they require 50 to 150kg N ha-1 per year (Karacic, 2005). Thus, up to 100 ha or plantations on over 25km of highways could be served with the ecosan manure. In respect to the actual distance between collection point and application area the mobile application unit (described above) could also be used for this purpose.

Apart form the advantages of efficiently recycling nutrients, removing CO_2 from the atmosphere and creating income this solution could also become an example for ecosan manure usage elsewhere. Especially for urban areas where no agricultural land is available in the proximity and when transportation costs need to be kept low the green strip solution might become an option.

6.7.2 Local food production with ecosan manure

Due to the advantages of human urine and faeces in comparison with waste water and commercial fertilisers a sound option is to use the ecosan manure for food production. Ready available special machinery for the application of liquid and solid manure facilitate the implementation. Certification conform current organic farming standards could not only increase the market value of the produce, but highlight the advantage of ecological sanitation. Alternatively to food crops, nursery and gardening companies producing seedlings and pot plants or cut flowers could make use of the ecosan manure.

Agricultural land potentially available can be located in about 20km distance from the park in north-western to north-eastern direction. At the current growth rate of Beijing and the fact that agriculture can often not compete for land prices with urbanization one must keep in mind that pressure to abandon this strategy is likely to grow in the future.

6.8 Ally with the lake expert group

The potential impact on the nutrient balance by the lake as the principal source of irrigation water has been demonstrated in chapter 1.7 in detail. Therefore a tight cooperation between the landscape and sanitation section with the group in charge of the water supply is needed.

A thoroughly exchange of the planned concepts should enable maximum synergetic effects between the two areas. For example, the economic and ecological benefit of the nitrogen removal from waste water for irrigation to below 15 mg l-1 must be questioned. Alternatively, the effort to reduce the nitrogen content in irrigation water could be saved and instead surplus nutrient exported from the park via urine and compost. Therefore, it might be an option to have two water flows from the treatment plants: One low in the concentration of P and N for the lake and the other primarily treated in respect two solids and pathogens for irrigation.

6.9 Monitoring of current nutrient status and impact of the system to be established system

The balancing act between under and over fertilisation requires, like in every other well managed agricultural or forestry system, that all major nutrient sources and sinks in the ecosystem are known as precise as possible. Research shows that unnecessary high fertiliser rates can easily be avoided, while maintaining peak yields if a straight forward nutrient monitoring is implemented (Mack et al., 2005). Further, limited knowledge is available on the nutrient management in public city parks and often the theoretical nutrient balance differs significantly to what is actually happening in an ecosystem. Therefore is is suggested that a comprehensive monitoring and validation program for mass and nutrient flow is implemented. The results will make continuing improvement of the system possible and gather crucial knowledge of this first of kind approach for transferral onto other public parks. Necessary mass flow records can be kept by the department responsible transport and processing of urine, compost and other relevant materials.

6.10 Hygiene monitoring

The importance of a comprehensive monitoring program in respect to hygiene safety is described in detail in the WHO's 'Guidelines for the safe use of waste water, excreta and grey water. Volume 4: Excreta and grey water use in agriculture'. For the Olympic Forest Park the layout of a hygiene monitoring program depends on the fate and use of the ecosan manure. Therefore, setting up such a program should follow after a decision on the basic concept is taken. A potential partner for the development and implementation of such a program is the Department of Environmental Engineering, University of Science and Technology Beijing (compare chapter 2).

7 Outlook

To make best use of the public momentum that is offered by the Olympic Games in August 2008 to advertise ecological sanitation and nutrient reuse it is important to have an integral approach ready as soon as possible. This approach could be transmitted to the visitors by posters, printed and other media as well as the above mentioned ecosan educational and information areas. Apart from the sanitary installations themselves actual implementation of treatment and reuse will take place after the games as time is needed to collect sufficient ecosan manure.

In order to develop a well structured approach for the utilisation of the ecosan manure from the ecological sanitary facilities in the Olympic Forest Park following work plan is suggested:

a) Firstly, detailed and exact information on the ecosanitary installation to be installed should be retrieved in cooperation with the contractors. On bases of these data the size and process of the collection and treatment facilities should be adjusted.

b) The decision to build an ecosan educational and information area should be taken and put into action (planting and training of promoters must start latest in May).

c) Establish a cooperation with an institution competent in soil science and prepare a soil map for the Olympic Forest Park and if applicable the alternative areas outside the park for ecosan manure application such as agricultural land or express way green strips.

d) Ally with lake expert group to get current state of planning and derive detailed information on the actually expected irrigation water quality.

e) Prepare on bases of c) and d) a spatial nutrient flow model that includes all sinks and build on this a plan for practical implementation including technical features and application dosages.

f) Estimated cost benefit of the ecological sanitary solution over alternative central waste water treatment.

g) Make two mobile application units available. Due to the initially high overall nutrient demand these units can be used as soon as the first lots of urine are available. Also if fixed pipe systems will be installed later such units will be of advantage for punctual nutrient application (e.g. at flower bed establishment) and for general watering/fertigation.

h) Design and print advertising material for the promotion during the 2008 Olympic Games.

i) Implement application concept developed under e) and initiate monitoring programs (nutrients/hygiene).

8 Reference list

Arianoutsou, M. (1989). Atmospheric deposition of nutrients in a coastal maquis ecosystem of northeastern Greece. *International Journal of Biometeorology*, *33*(2), 124-130.

Chen, X. Y., & Mulder, J. (2007). Atmospheric deposition of nitrogen at five subtropical forested sites in South China. *Science of The Total Environment*, *378*(3), 317-330.

Cole, D. W. (1995). Soil nutrient supply in natural and managed forests. *Plant and Soil*, *168-169*(1), 43-53.

Elliott, K. J. B. (2002). Aboveground biomass and nutrient accumulation 20 years after clear-cutting a southern Appalachian watershed. *Canadian Journal of Forest Research*, *32*, 667-683.

Ernst, M., Sperlich, A., Zheng, X., Gan, Y., Hu, J., Zhao, X. et al. (2007). An integrated wastewater treatment and reuse concept for the Olympic Park 2008, Beijing. *Desalination*, *202*(1-3), 293-301.

Fang, L. L., Xue, L. G., & Yong, L. X. (2004). Assessment on the pollution of nitrogen and phosphorus of Beijing surface water based on GIS system and multivariate statistical approaches. *Journal of Environmental Sciences (China)*, *16*(6), 981-986.

Gao, X. Z., T. Shen, & Y. Zheng. (2002). *Practical Manure Handbook*. Chinese Agricultural Publishing House, Beijing, China.

Germer, J. U. (2007). Urin und Fäzes als Quelle von Pflanzennährstoffen (in review). In *Komposttoiletten*. Ökobuch Verlag, Staufen, Germany.

Guinot, B. R. (2006). Impact of vertical atmospheric structure on Beijing aerosol distribution. *Atmospheric Environment*, *40*, 5167-5168.

Hatch, D., Goulding, K., & Murphy, D. (2002). Nitrogen. In P. Haygarth & S. Jarvis (Hrsg.), *Agriculture, Hydrology and Water Quality* (S.. 7-27). Wallingford, UK: CAB International.

Johnson, D., Henderson, G., & Todd, D. (1988). Changes in nutrient distribution in forests and soils of Walker Branch watershed, Tennessee, over an eleven-year period.

Biogeochemistry, *5*(3), 275-293.

Johnson, P. G., Koenig, R. T., & Kopp, K. L. (2003). Nitrogen, Phosphorus, and Potassium Responses and Requirements in Calcareous Sand Greens. *Agron J*, *95*(3), 697-702.

Jönsson, H., Stenstrom, T., Svensson, J., & Sundin, A. (1997). Source separated urine - nutrient and heavy metal content, water saving and faecal contamination. *Water Science and Technology*, *35*(9), 145-152.

Jönsson, H., & Vinneras, B. (2004). Adapting the nutrient content of urine and faeces in different countries using FAO and Swedish data. *Ecosan Closing the loop. Proc. 2nd Intern. Symp. Ecological Sanitation, April 2003*, 623-626.

Karacic, A. (2005). *Production and Ecological Aspects of Short Rotation Poplars in Sweden*. Dept. of Short Rotation Forestry, SLU. Acta Universitatis agriculturae Sueciae vol. 2005:13.

Knops, J. M. H., & Tilman, D. (2000). Dynamics Of Soil Nitrogen And Carbon Accumulation For 61 Years After Agricultural Abandonment. *Ecology*, 88-98.

Kvarnström, E., Emilsson, K., Richert Stintzing, A., Johansson, M., Jönsson, H., Petersens, E., et al. (2006). *Urine Diversion: One Step Towards Sustainable Sanitation. Stockholm Environment Institute, Stockholm, Sweden*. Stockholm, Sweden: Stockholm Environment Institute.

Liu, G., Wu, W., & Zhang, J. (2005). Regional differentiation of non-point source pollution of agriculture-derived nitrate nitrogen in groundwater in northern China. *Agriculture, Ecosystems & Environment*, *107*(2-3), 211-220.

Liu, X., Ju, X., Zhang, Y., He, C., Kopsch, J., & Fusuo, Z. (2006). Nitrogen deposition in agroecosystems in the Beijing area. *Agriculture, Ecosystems & Environment*, *113*(1-4), 370-377.

Liu, Z., Qun, M., An, W., & Sun, Z. (2007). An application of membrane bio-reactor process for the wastewater treatment of Qingdao International Airport. *Desalination*, *202*(1-3), 144-149.

Luo, L., Qin, B., Yang, L., & Song, Y. (2007). Total inputs of phosphorus and nitrogen by wet deposition into Lake Taihu, China. *Hydrobiologia*, *581*(1), 63-70.

Lynch, J. A., Horner, K. S., Grimm, J. W., & Carrick, H. C. (2006). *Atmospheric Deposition: Spatial and Temporal Variations In Pennsylvania 2005*. Penn State Institutes of the Environment, The Pennsylvania State University, USA.

Mack, U. D., Feger, K., Gong, Y., & Stahr, K. (2005). Soil water balance and nitrate leaching in winter wheat–summer maize double-cropping systems with different irrigation and N fertilization in the North China Plain*J. Plant Nutr. Soil Sci.*, *168*, 454-460.

Qian, Y., Wen, X., & Huang, X. (2007). Development and application of some renovated technologies for municipal wastewater treatment in China. *Frontiers of Environmental Science & Engineering in China*, *1*(1), 1-12.

Rinklebe, J., & Makeschin, F. (2003). Der Einfluss von Acker- und Waldnutzung auf Boden und Vegetation - ein Zeitvergleich nach 27 Jahren. The Impact of Arable and Forest Land Use on Soil and Vegetation - A Comparison after 27 Years. *Forstwissenschaftliches Centralblatt*, *122*(2), 81-98.

Rothstein, D. E. (2005). Nitrogen Management in a Fraser Fir (Abies fraseri Pursh Poir.) Christmas Tree Plantation: Effects of Fertilization on Tree Performance and Nitrogen Leaching. *Forest Science*, *51*, 175-184.

Shuncai, S., & Chen, Z. (2000). Nitrogen distribution in the lakes and lacustrine of China. *Nutrient Cycling in Agroecosystems*, *57*(1), 23-31.

Tang, J. C. C. (2004). Assessment of groundwater contamination by nitrates associated with wastewater irrigation: A case study in Shijiazhuang region, China. *Hydrological Processes*, *18*(12), 2303-2312.

Udert, K., Larsen, T., & Gujer, W. (2006). Fate of major compounds in source-separated urine. *Water Sci Technol*, *54*(11-12), 413-20.

Wang T.J., Zhang Y., Zhang M., Hu Z.Y., Xu C.K., & Zhao Y.W. (2003). Atmospheric sulfur deposition and the sulfur nutrition of crops at an agricultural site in Jiangxi province of China. *Tellus B*, *55*, 893-900.

Whitehead, D. C. (1990). Atmospheric ammonia in relation to grassland agriculture and livestock production. *Soil Use and Management*, *6*(2), 63-65.

Yu, H., Li, Z., Gong, Y., Mack, U., Feger, K., & Stahr, K. (2006). Water drainage and nitrate leaching under traditional and improved management of vegetable-cropping systems in the North China Plain. *Journal of Plant Nutrition and Soil Science*, *169*, 47-51.

Zhang, C., Chen, F., Miao, S., Li, Q., & Xuan, C. (2007). Influences of urbanization on precipitation and water resources in the metropolitan Beijing area. *21st Conference on Hydrology, NASA/GSFC/GMAO, Greenbelt, MD, USA*.

Zhang, X., Hu, L., Bian, X., Zhao, B., Chai, F., & Sun, X. (2007). The most economical irrigation amount and evapotranspiration of the turfgrasses in Beijing City, China. *Agricultural Water Management*, *89*(1-2), 98-104.

Zhang, X. Y., Gong, S. L., Arimoto, R., Shen, Z. X., Mei, F. M., Wang, D., u. a. (2003). Characterization and Temporal Variation of Asian Dust Aerosol from a Site in the Northern Chinese Deserts. *Journal of Atmospheric Chemistry*, *44*(3), 241-257.

Appendix 1: Sanitary block installation assessment sheet

Sanitary block					**Date**
Hand-Washbasins					
Restroom (female/male/special)					
Number					
Origin of hand wash water (e.g. rain, lake, municipal)					
Grey water disposal					
(e.g. separate collection, with brown water or urine, local infiltration)					
Toilets					
Restroom (female/male/special)					
Type (sitting/pan/urinal)					
Number					
Urine separation (yes/no)					
Fush (yes/no)					
- urine flush water amount (l)					
- faeces flush water amount (l)					
- origin of flush water (grey water/rain/urine/municipal/ground water/lake)					
Dry collection of faeces (yes/no)					
- additive material (yes/no)					
- type of material (e.g. saw dust, micro-organisms)					
Separate collection of toilet paper (yes/no)					
Collection tanks					
Grey water/Yellow water (urine)/Black water (yellow&brown)/					
Brown water (faeces&flush)/dry faeces					
Number					
Size (m^3) – each					
Remarks					

Appendix 2: Olympic forest park species list (translated form chinese version, common names and families appended)

Specie	Common name	Family
Acer truncatum Bunge	Purple blow maple	Aceraceae
Heteropappus altaicus Novopokrov.	X	Asteraceae
Inula magnifica Lipsky	Sunray Flower	Asteraceae
Ixeris crunchiness (Thunb.) Nakai	X	Asteraceae
Rudbeckia hirta L.	Blackeyedsusan	Asteraceae
Taraxacum officinale L.	Common Dandelion	Asteraceae
Berberis vulgaris L.	Common Barberry	Berberidaceae
Catalpa bungei C.A.Mey.	X	Bignoniaceae
Catalpa ovata G. Don	Chinese Catalpa	Bignoniaceae
Capsella bursa-pastoris (L.) Medik.	Shepherd's Purse	Brassicaceae
Lepidium latifolium L.	Broadleaf Pepperweed	Brassicaceae
Orychophragmus violaceus (L.) O.E.Schulz	X	Brassicaceae
Buxus microphylla Siebold & Zucc.	Littleleaf Boxwood	Buxaceae
Lonicera japonica Thunb.	Chinese honeysuckle, Japanese honeysuckle	Caprifoliaceae
Lonicera maackii (Rupr.) Herder	Amur honeysuckle, Amur honeysuckle bush	Caprifoliaceae
Sambucus williamsii Hance	X	Caprifoliaceae
Weigela florida (Bunge) A. DC.	Oldfashioned weigela	Caprifoliaceae
Euonymus bungeanus Maxim.	Winterberry	Celastraceae
Euonymus japonicus Wall.	Japan Euonymus	Celastraceae
Kochia scoparia (L.) Schrad.	Fireweed, Summer Cypress	Chenopodiaceae
Convolvulus arvensis L.	Field Bindweed	Convolvulaceae
Cornus alba L.	Dogwood	Cornaceae
Juniperus chinensis L.	Chinese juniper	Cupressaceae
Juniperus sabina L.	Sabina, Savin	Cupressaceae
Platycladus orientalis (L.) Franco	Oriental Arbor-vitae	Cupressaceae
Matteuccia struthiopteris (L.) Todaro	Ostrich Fern	Dryopteridaceae
Diospyros kaki L.f.	Japanese Persimmon	Ebenaceae
Elaeagnus umbellata Thunb.	Autumn Oleaster or Olive	Elaeagnaceae
Albizzia julibrissin Durazz.	Silktree Siris	Fabaceae
Amorpha fruticosa Linn.	False Indigo-bush	Fabaceae
Lespedeza floribunda Bunge	X	Fabaceae
Robinia hispida L.	Bristly locust	Fabaceae
Robinia pseudoacacia Linn.	Black Locust, Post Locust	Fabaceae
Sophora japonica L.	Chinese scholartree	Fabaceae
Trifolium repens L.	X	Fabaceae
Wisteria sinensis (Sims) Sweet	Purplevine	Fabaceae
Ginkgo biloba L.	Ginkgo	Ginkoaceae
Deutzia grandiflora Bunge	Big-flowered Deutzia	Hydrangeaceae
Deutzia parviflora Bunge	Small-flowered Deutzia	Hydrangeaceae
Juglans regia L.	Walnut Tree, English Walnut	Juglandaceae
Lagopsis supina (Stephan) Ik.-Gal. ex Knorring	X	Lamiaceae
Hemerocallis fulva L.	X	Liliaceae
Ophiopogon japonicus (L. f.) Ker Gawler	Dwarf Lilyturf	Liliaceae

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Buddleia davidii Franch.	X	Loganiaceae
Lagerstroemia indica L.	Common Carpemyrtle	Lythraceae
Magnolia denudata Desr.	X	Magnoliaceae
Hibiscus syriacus L.	Rose-of-Sharon	Malvaceae
Toona sinensis M.Roem.	X	Meliaceae
Morus alba L.	Mulberry	Moraceae
Forsythia suspensa (Thunb.) Vahl	Weeping forsythia	Oleaceae
Fraxinus chinensis Roxb.	Chinese ash	Oleaceae
Jasminum nudiflorum Lindl.	Winter jasmine	Oleaceae
Oxalis corniculata Linn.	Creeping Woodsorrel or Oxalis	Oxalidaceae
Picea koraiensis Nakai	Korean spruce, Koya	Pinaceae
Picea meyeri Rehder & E.H. Wilson	Meyer spruce	Pinaceae
Picea wilsonii Mast.	Wilson Spruce	Pinaceae
Pinus bungeana Zucc. ex Endl.	Pine	Pinaceae
Pinus tabulaeformis Carriere	Chinese pine	Pinaceae
Platanus hispanica Ten.	X	Platanaceae
Poa annua Linn.	Annual Bluegrass	Poaceae
Polygonum aviculare L.	Common or Prostrate Knotgrass	Polygonaceae
Portulaca oleracea L.	Purslane	Portulacaceae
Amygdalus davidiana Hort. ex Dippel	David Peach	Rosaceae
Armeniaca vulgaris Lam	Common Apricot	Rosaceae
Cotoneaster horizontalis Decne.	X	Rosaceae
Cotoneaster multiflorus C.A.Mey.	Manyflower Cotoneaster	Rosaceae
Crataegus cuneata Siebold & Zucc.	Nippon Hawthorn Fruit	Rosaceae
Duchesnea indica (Andrews) Focke	India Mockstrawberry	Rosaceae
Kerria japonica (L.) DC.	X	Rosaceae
Malus micromalus Makino	X	Rosaceae
Potentilla chinensis Ser.	Chinese Cinquefoil	Rosaceae
Prunus triloba Stapf	Flowering Almond	Rosaceae
Pyracantha fortuneana (Maxim.) H.L.Li	X	Rosaceae
Rosa xanthina Lindl	Manchurian Rose	Rosaceae
Sorbaria sorbifolia (L.) A.Br.	Ural False-spiraea	Rosaceae
Spiraea salicifolia L.	Willow-leaved spiraea	Rosaceae
Armeniaca sibirica (L.) Lam	Siberian Apricot	Rosaceae
Populus tomentosa Carr	Chinese White Poplar	Salicaceae
Salix matsudana Koidzumi	Corkscrew Willow	Salicaceae
Koelreuteria paniculata Laxm.	Goldenrain tree	Sapindaceae
Paulownia tomentosa (Thunb.) Sieb. & Zucc.	Empress Tree	Scrophulariaceae
Ailanthus altissima (P. Mill.) Swingle	Ailanthus, Tree of heaven, Copal tree	Simaroubaceae
Tamarix chinensis Lour.	Chinese or China Tamarisk	Tamaricaceae
Taxus cuspidata Siebold & Zucc.	X	Taxaceae
Tilia mandschurica Rupr. et Maxim.	X	Tiliaceae
Tilia mongolica Maxim.	X	Tiliaceae
Ulmus pumila L.	Chines-, Siberian Elm	Ulmaceae

Appendix 2: Olympic forest park species list (translated form chinese version, common names and families appended)

Vitex chinensis Mill.	X	Verbenaceae
Viola philippica Cav.	Philippine or Chinese Violet	Violaceae
Parthenocissus tricuspidata (Sieb. & Zucc.) Planch.	Boston Ivy	Vitaceae
Tribulus terrestris L.	Bullhead	Zygophyllaceae

Appendix 3: Contact list

Contact	**Institution**	**Position**	**Expertise**	**email**	**phone**
Chenxi	Beijing Tsinghua University	Ass. to Wenjing, Dr. Lu	Compost/Environ. Standards	zcx@mails.thu.edu.cn	
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Appendix 3: Contact list

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Essential key persons are: Prof. Dr. Jie Hu over viewing all landscape, building and material flow related tasks, Mr. Weijia He in charge of all physical installations related to the material flows, Dr. Jian Zhang assigned for the erection and fitting of sanitary blocks, Dr. Li Zifu suggested for OFP hygiene monitoring and Dr. Zhang Shu Xiang suggested for the OFP nutrient monitoring.